The Effects of Eye Gaze and Emotional Facial Expression on the Allocation of Visual Attention

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Submitted for the degree of Doctor of Philosophy

July 2006

Abstract

This thesis examines the way in which meaningful facial signals (i.e., eye gaze and emotional facial expressions) influence the allocation of visual attention. These signals convey information about the likely imminent behaviour of the sender and are, in turn, potentially relevant to the behaviour of the viewer. It is already well established that different signals influence the allocation of attention in different ways that are consistent with their meaning. For example, direct gaze (i.e., gaze directed at the viewer) is considered both to draw attention to its location and hold attention when it arrives, whereas observing averted gaze is known to create corresponding shifts in the observer's attention. However, the circumstances under which these effects occur are not yet understood fully. The first two sets of experiments in this thesis tested directly whether direct gaze is particularly difficult to ignore when the task is to ignore it, and whether averted gaze will shift attention when it is not relevant to the task. Results suggest that direct gaze is no more difficult to ignore than closed eyes, and the shifts in attention associated with viewing averted gaze are not evident when the gaze cues are task-irrelevant. This challenges the existing understanding of these effects. The remaining set of experiments investigated the role of gaze direction in the allocation of attention to emotional facial expressions. Without exception, previous work looking at this issue has measured the allocation of attention to such expressions when gaze is directed at the viewer. Results suggest that while the type of emotional expression (i.e., angry or happy) does influence the allocation of attention, the associated gaze direction does not, even when the participants are divided in terms of anxiety level (a variable known to influence the allocation of attention to emotional expressions). These findings are discussed in terms of how the social meaning of the stimulus

can influence preattentive processing. This work also serves to highlight the need for general theories of visual attention to incorporate such data. Not to do so fundamentally risks misrepresenting the nature of attention as it operates out-with the laboratory setting.

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Acknowledgements

Greatest thanks go to my supervisor Steve Langton for his support and advice throughout this project. As my second supervisor, I am also grateful to Vicki Bruce for sage council and a critical pair of eyes. This research was supported by an ESRC Postgraduate Training Award, PTA-030-2002-00724.

Publications

Experiment 10 (Chapter 4) has been accepted for publication:

Cooper, R. M. & Langton, S.R.H. (2006). Attentional bias to angry faces using the dot-probe task? It depends when you look for it. *Behaviour Research and Therapy*, 44, 1321 - 1329.

Chapter 1

General Introduction

Our brains are constantly bombarded with information from our senses. For example, as you read the words on this page your brain is receiving not only the appropriate visual information on which you are trying to concentrate, but also other visual, auditory, olfactory, and tactile information from a huge variety of sources. The mechanism which serves to filter this information is called attention. Only a fraction of the incoming information is selected by attention for further processing (e.g., Broadbent, 1952; Sperling, 1960). The extent to which information from these potential sources is selected depends on at least two factors: 1) the behavioural relevance of the information to ongoing task goals and 2) the ability of that information to capture attention regardless of those goals. Consequently, information relevant to the current task is processed more deeply than task-irrelevant, unattended information (e.g., Treisman, 1960). However, the processing of task-irrelevant information increases markedly when that information is sufficiently salient (e.g., Moray, 1953; although see Harris, Pashler, & Coburn, 2004). This ability to process certain information regardless of task demands has been characterised as a “circuit breaker” of voluntary attention (Corbetta and Shulman, 2002) which ensures the processing of stimuli with potential behavioural significance. From an evolutionary perspective, an individual with a system that allocates attention to the appearance of sudden and unexpected items (e.g., an approaching predator) would be at an advantage compared with someone who could not disengage from their current activity.

Arguably, the most biologically important (and in this sense, salient) stimuli we encounter regularly are faces (Ellis, 1981). Faces contain a large amount of socially and evolutionarily relevant information such as, age, race, sex, attractiveness, emotion, and gaze direction. The importance of these stimuli is reflected in the existence of neural circuits dedicated to the processing of facial information (Farah, Wilson, Drain, & Tanaka, 1998; Perrett, Hietanen, Oram, & Benson, 1992). Furthermore there is evidence that the relationship between faces and attention is ‘special’ in the sense that faces draw attention to their location (Hershler & Hochstein, 2005) and are particularly difficult to ignore, even when they are not relevant to current goals (Jenkins, Lavie, & Driver, 2003). Thus, faces may be prioritised for processing by the attentional system compared to other visual stimuli.

If the allocation of attention to faces is prioritised relative to other classes of visual stimuli it is reasonable to suppose that this allocation of attention might also depend on different characteristics of the face (e.g., emotional expression). This idea is supported by data which suggest that angry faces capture attention more efficiently than do happy or neutral faces (Öhman, Lundqvist, & Esteves, 2001). Furthermore, faces with gaze directed at the viewer (direct gaze) are thought to capture attention more efficiently than similar faces with averted gaze (von Grünau & Anston, 1995). These studies suggest that meaningful facial signals can influence the way in which attention is allocated to a face.

Furthermore, once attention reaches the face, the specific signals that are being communicated can have very different implications for what attention does next. These signals are only understood fully with the ability to understand gaze direction (e.g., she is attracted to me; he is scared of something over there) and all have a signal-specific attention component attached to the viewer’s response (e.g., I should look back at the attractive person; I should also attend to the scary thing).

This thesis investigates the relationship between meaningful facial signals and visual attention. Throughout, the focus of the experiments in this thesis is on the role that eye gaze has in the allocation of attention to faces, both when they are free from emotional expression and when they express emotion. Given that such signals are so regularly encountered when interacting with other humans, their study will help illuminate the processes by which attention operates in such scenarios, something that has traditionally been neglected in the study of attention (Fox, 2005). This work also serves to highlight the need for general theories of visual attention to incorporate such data or risk fundamentally misrepresenting the nature of attention as it operates out-with the laboratory setting (Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003).

Despite an increase in interest in this area over recent years there is still much that is not understood. For example, while eye gaze is thought to both draw (von Grünau & Anston, 1995) and shift (Langton & Bruce, 1999) attention, it is not known to what extent these effects are dependent on the stimulus features per se, or the relevance of those features to the observer's goals. Two questions that arise from this are; 1) does direct gaze still draw attention if the observer's task is to try and ignore it, and 2) does averted gaze still shift attention when it is irrelevant to the task? These questions are addressed in Chapters 2 and 3 respectively.

Furthermore, work looking at how attention is allocated to emotional facial expressions has exclusively presented faces with eyes directed at the viewer (e.g., Öhman et al, 2001). This means that these previous studies have confounded the signal conveyed by emotional expression with the gaze signal that is also being communicated. As a result it is currently unclear whether any observed attentional effects related to the presentation of the face are a function of the emotional expression per se, or the fact that the expression is directed towards the viewer. This issue is addressed in Chapter 4. In turn, Chapter 5 examines how individual differences in anxiety influence the allocation of attention to these different facial signals.

The following section contains a brief review of the evidence showing how the allocation of visual attention generally proceeds. This is followed by a review of the evidence suggesting faces are ‘special’ in terms of how they are processed relative to other visual objects. This, in turn, is followed by evidence showing how gaze and emotional expression are processed. The existing studies that look at the allocation of attention in response to faces and specific facial signals are then discussed.

Control of Visual Attention

A fundamental distinction that has driven enquiry into the study of visual attention is between measuring attention as it proceeds in a top-down (goal-driven), or in a bottom-up (stimulus-driven) fashion (e.g., Yantis, 1998); a distinction first made by William James (1890) who referred to active and passive modes of attention respectively. Attention is defined as being goal-driven when its control is dependent on the intentions of the observer. For example, when searching a crowd of people for a tall friend, attention will tend to select preferentially any tall people in the visual field for further analysis. In contrast, stimulus-driven attention is defined as such when it is controlled by salient aspects of the visual field which are not necessarily compatible with the observer’s goals. For example, while trying to search for the tall friend a flashing traffic light might seem to draw attention automatically.

While this distinction is useful, the boundaries between the two modes of attention are, in reality, somewhat blurred. Thus, a perceptually salient aspect of the visual field such as a flashing light may draw attention to its location in an automatic fashion under most circumstances, but some argue that this will be contingent upon the attentional control settings of the viewer (Folk, Remington, & Wright, 1994). This means that the person's desire to complete the task (i.e., their top down attentional setting) may override the allocation of attention to certain kinds of stimuli that would automatically attract attention under other circumstances.

Regardless of the attentional control settings, for stimulus-driven effects to reach awareness there must be perceptual processes that automatically analyse the perceptual field. Recognition that these processes are at work has led to some consensus about a distinction between preattentive and postattentive perceptual processes. The former is fast, automatic, and operates in parallel, with its main role to delineate objects from the surroundings. In contrast, the latter is slow, intentional, and operates serially (e.g., Johnston & Dark, 1986; Posner, 1978; Treisman, 1988). Traditionally, it has been thought that the preattentive mechanism operates on purely low-level stimulus features such as colour and orientation while the postattentive mechanism is concerned with the more complex role of interpreting the information that has been selected (e.g., Wolfe, 1998). Again, while useful, this distinction is also becoming somewhat blurred with increasing evidence that preattentive mechanisms can direct attention towards socially meaningful stimuli such as faces (e.g., Hershler & Hochstein, 2005; see later in this chapter for a fuller discussion of this evidence).

The experiments reported in this thesis relate to how attention responds as a result of different social signals being perceived. By their very nature, then, they are measuring the effects of different stimulus types (e.g., an angry face with averted gaze) on the control of visual attention. In all experiments in this thesis, the critical stimuli are unrelated to the set tasks. Therefore, it is assumed that any attentional effects that are measured in response to the presentation of these stimuli should be stimulus-driven. Accordingly, the rest of this section will concentrate on reviewing research relating to stimulus-driven control of attention.

Stimulus-Driven Control of Attention

One of the most common tasks used to study the deployment of both stimulus-driven, and goal-driven visual attention, is the visual search task (e.g., Treisman and Paterson, 1984; Wolfe, 1998; Theeuwes, 1994). The standard version of this paradigm requires search for a target which is embedded amongst a set of distractors. By varying the number of distractors and measuring the subsequent effect this has on the time taken to locate the target, it is possible to draw inferences about the allocation of attention. If increasing the number of distractors has little or no effect on search times (an increase of 0-10 ms per item), this would traditionally[1] be categorised as a parallel search – all items are processed at once. However, if the search time increases markedly with the addition of extra distractors (>20 ms per item), this would traditionally be categorised as a serial search; each item is processed in sequence until the target is reached.

Importantly, for the study of stimulus-driven control of attention, it is possible to examine the processing of different kinds of task-irrelevant stimuli by measuring the degree to which they interfere with the search task (i.e., slow down search times).

[1] Wolfe (1998) has argued that the terms ‘parallel’ and ‘serial’ to describe visual search performance are misleading because they imply there are two qualitatively different types of search which the data does not always support. Instead, he has argued for a less dichotomous approach to labelling visual search performance with search being described as either more, or less, efficient.

If a stimulus captures attention regardless of the observer's goals, this is good evidence that it is an automatic, stimulus-driven process (Shiffrin & Schneider, 1977). Using a procedure in which participants searched for a target in a display while ignoring irrelevant distractors, Yantis & Jonides (1984) demonstrated that abrupt visual onsets (the appearance of an additional unexpected item during search) reliably capture attention. In real-world scenarios, such events are likely to be important because they reflect a sudden change in the visual field which may require an immediate response, such as the appearance of a new object (Breitmeyer & Ganz, 1976).

However, despite the assumption that this procedure measures task-irrelevant processing, it is possible to argue that the abrupt onsets are, in fact, task-relevant. This is because the beginning of each trial is signalled by the onset of the stimulus array, thus making 'stimulus onset' a task-relevant dimension. To illustrate this point, Gibson and Kelsey (1998) gave participants a search task in which a task-irrelevant red singleton could appear as a precue to the rest of the display. Under normal task conditions this precue failed to capture attention. However, when the whole search display was made red, the appearance of red now signalled the start of the search trial. Under these conditions the red precue reliably captured attention, thus, its ability to capture attention was contingent on its relevance to the task.

This finding, and the resulting conclusions which argue against the existence of pure stimulus-driven shifts in attention, is potentially damaging for the vast majority of experiments claiming to show such evidence. These would potentially have to be reinterpreted as showing evidence only for contingent involuntary orienting as opposed to pure stimulus-driven orienting (Remington, Folk, & Mclean, 2001).

However, Franconeri, Simons, & Junge, (2004) tackled this confound by requiring participants to make a saccade away from the computer monitor between trials. The stimulus display changed during this saccade and since the particpants were not looking at the screen, the changes were never seen. This ensured that the onset of the trial on the screen was never a task-relevant factor. They found that under these conditions, task-irrelevant abrupt onsets were able to capture attention.

This ability of onset stimuli to capture attention is further supported by evidence obtained using a task known as the Posner cueing paradigm (Posner, 1978; 1980). In this paradigm, a central fixation cross is flanked by two boxes. The task is to press a button whenever a target appears in one of the boxes. The onset of the target is preceded by a cue (i.e., an abrupt onset[2]) whereby one of the boxes flashes. Despite the fact that participants are fully aware that the location of the cue does not reliably predict the location of the target (target appears in the cued location 50% of the time) responses are faster when the location of the cue and the target are congruent compared to when they are not.

A modification of this procedure by Remington, Johnston, & Yantis (1992) presented four potential target locations and trials in which the cue never predicted where the target would appear. Even under these circumstances, where participants explicitly knew the cue was entirely unhelpful, they could not ignore this information. Response times to detect the target were always slower in this condition compared to others in which either the target was cued, or all (or none) of

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[2] The cue in these studies is not commonly referred to as an abrupt onset. Rather it has been categorised as a “transient event” (e.g., Friesen, Ristic, & Kingstone, 2004). However, both refer to essentially the same thing; namely a luminance change in a non-predictive location. As such I call both ‘abrupt onsets’ for the purposes of this review.

the locations were cued. These experiments, based on the Posner cueing paradigm, combined with the evidence from the visual search tasks, provide compelling support for the notion that abrupt visual onsets capture attention in an automatic fashion.

Until recently it was believed that such reflexive, stimulus-driven shifts in attention could only be produced by cues presented in the periphery (Yantis, 1998). Such cues would elicit shifts of attention to their location while meaningful directional cues presented at fixation (e.g., an arrow) could only produce voluntary (i.e., goal-driven) shifts in attention (Jonides, 1981). This idea has been subsequently challenged by the finding that centrally presented eye gaze stimuli produce reflexive shifts in attention (Friesen & Kingstone, 1998; Langton & Bruce, 1999; Driver, Davis, Ricciardelli, Kidd, Maxwell, & Baron-Cohen, 1999). These studies employed a variation of the Posner cueing paradigm and found, entirely compatible with the results with abrupt onset cues, that responses to targets at cued locations were faster than non-cued locations, even though the cue did not reliably predict the target location. Indeed, Driver et al (1999) found faster responses in cued trials even when the cue predicted the target location on only 20% of trials.

These results go against what would have been predicted from an understanding of previous attention research and highlight the importance that the study of evolutionarily important stimuli (such as eye gaze) can have on our understanding of cognitive mechanisms such as attention (Kingstone et al, 2003). However, it is interesting to note that such data have yet to be incorporated into any existing theory of visual attention. This underlines the fact that attention research has traditionally been concerned with the allocation of attention to attributes of stimuli such as colour and orientation rather than meaning (Fox, 2005). I return to this issue in Chapter 6.

To summarise so far, there is strong evidence that stimuli which are of immediate behavioural importance such as sudden onsets and another's gaze direction can control attention in a reflexive, stimulus-driven fashion (although the existence of effects that are entirely stimulus-driven remains contentious; Boot, Brockmole, & Simons, 2005). The next section reviews evidence concerning how we process the human face, arguably the most important stimulus we encounter on a regular basis, and suggests that it may be 'special' compared with the processing of other kinds of stimuli. It will then go on to show how the relationship between face processing and attention may also be 'special'.

Evidence for Faces Being 'Special'

In this section I will consider evidence that the processing of faces may be distinct from the processing of other classes of visual stimuli. This evidence comes from three different kinds of research: psychological, neuropsychological, and neural. The psychological evidence will be presented first.

Psychological Evidence

A classic demonstration of the difference in the processing of faces compared with other non-face stimuli was reported by Yin (1969). Yin revealed that inverting a stimulus (i.e., rotating it through 180˚) has a more detrimental effect on face recognition than object recognition. It is generally thought that this difference is a result of fundamentally different modes of processing which exist for faces and objects, with faces being processed holistically and objects being processed in a

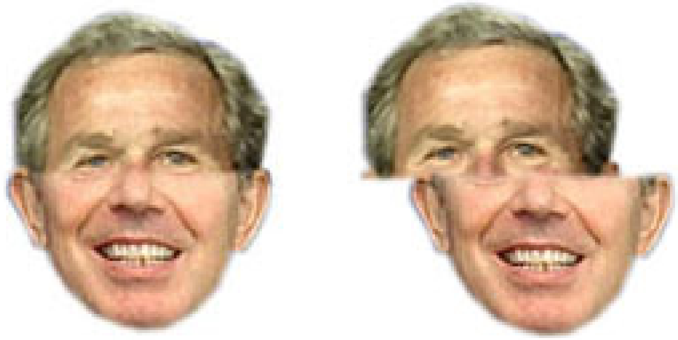

Figure 1.1: Composite facial images (following Young et al, 1987). Recognition of the separate top and bottom halves is more difficult when the faces are aligned than when they are not. Here, the top half is George Bush and the bottom half is Tony Blair.

more part-based fashion (e.g., Carey & Diamond, 1977; Rhodes, Brake, & Atkinson, 1993; Sergent, 1984).

In support of the holistic versus part-based account of face processing, Young, Hellawell, and Hay (1987) created new facial images which contained the top and bottom portions of two different famous people's faces (see Figure 1.1). The crucial manipulation in their experiment was that these faces could either be aligned or misaligned and participants had to identify the top or bottom portion of each face. Results showed that responses were slower when the images were aligned compared with when they were not, and this pattern disappeared when the images were inverted. This indicates that even though the information in the two different face halves is identical in each condition, when they are not aligned they can be treated as separate pictures. However, when they are aligned, it is harder to ignore the percept of a whole face made up from the two different halves, hence, response times are slowed down in this condition. This strongly suggests that the upright aligned images were processed holistically but the non-aligned, and inverted aligned ones were not.

Further evidence of the unique nature of face processing compared with the processing of non-face stimuli comes from a study looking at the recognition memory of parts of faces (Tanaka & Sengco, 1997). In a study phase, participants were shown pictures of faces, inverted faces, scrambled faces, and houses. Then, in a later test phase, participants' memory was tested for individual items from the previously seen images when presented in, (a) isolation, (b) a new configuration, and (c) the original face seen at test (see Figure 1.2). For the face stimuli, performance was best when the test items were presented in the context of the original face. However, the three other conditions (inverted faces, scrambled faces, and houses) produced equivalent memory for the parts regardless of whether they were tested in isolation or in the original context. Again, this suggests that faces are represented more holistically than other, less face-like, stimuli.

Neuropsychological Evidence

Clear evidence of the important status ascribed to face processing is revealed by observing how infants respond to faces. Such study indicates the extent to which face-specific processing might be biologically 'hard-wired'. Goren, Sarty, & Wu (1975) presented new-born infants (mean age 9 minutes) with four different stimuli; a schematic face, two scrambled faces, and a blank face. Each stimulus was shown in turn, with infants' head and eye movements recorded as the stimuli were moved in a 180° arc. Infants demonstrated a clear preference to look at the schematic face over the non-face controls. This experiment, and a subsequent replication (Johnson, Dziurawiec, Ellis, & Morton, 1991; although see Simion, Valenza, Cassia, Turati, & Umilta, 2002, for an alternative interpretation), suggest there is an innate processing bias which favours faces over other stimuli. This

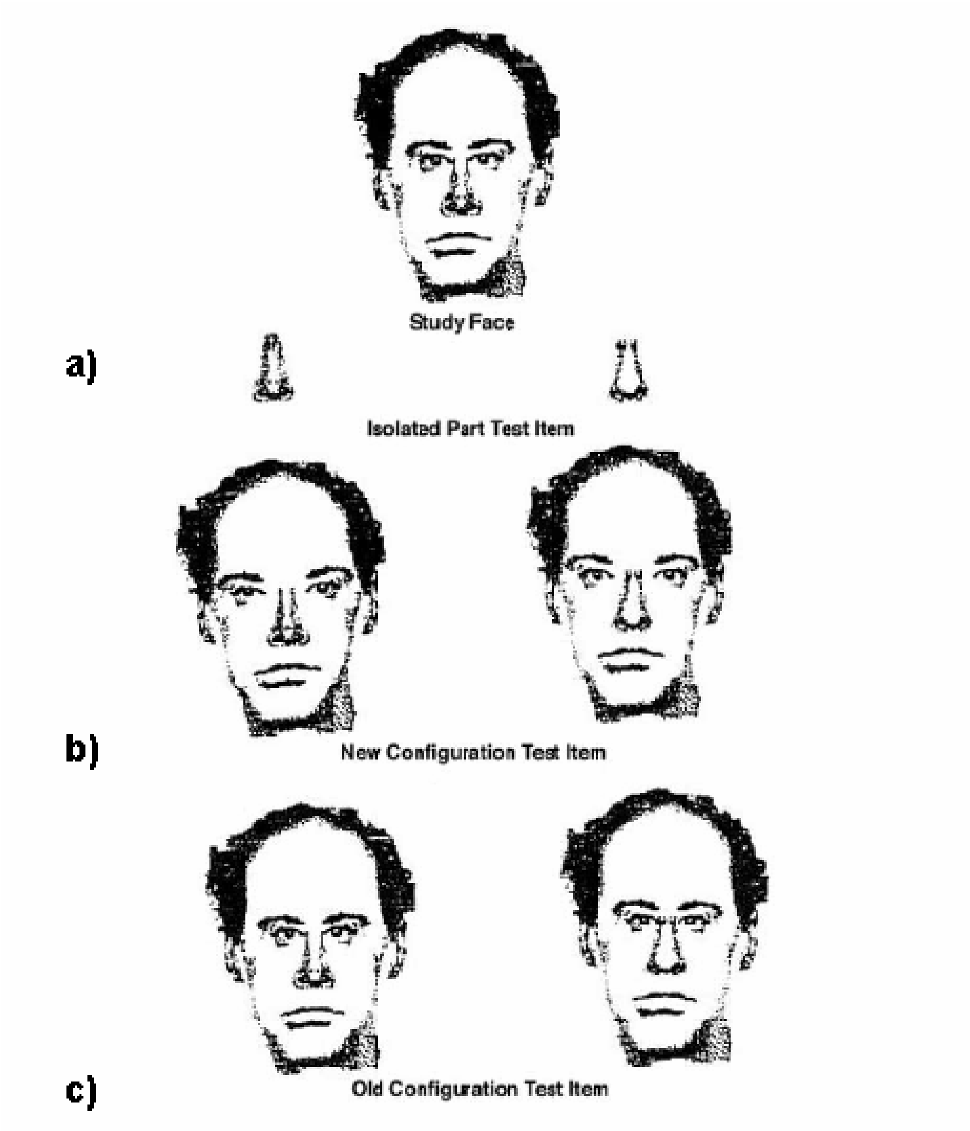

Figure 1.2: An example of the stimuli used by Tanaka and Sengco (1997). Participants' memory for specific features (in this case the nose) is tested by presenting the items in (a) isolation (b) within the face in a new configuration and (c) in the original face seen at learning. Performance is best when the test item is seen in the original configuration.

provides some evidence of the existence of a specific 'module' which may be dedicated to the processing of faces (Fodor, 1983).

Further evidence of the specificity of face processing comes from the existence of a neuropsychological deficit known as prosopagnosia. It refers to an inability to recognise familiar faces which can occur following brain damage or can arise as a result of a congenital neurological disorder. Importantly, object recognition abilities can often remain intact (Ellis & Young, 1989) and there is evidence of a double dissociation between face and object processing with some patients showing object agnosia without prosopagnosia (Albert, Reches, & Silverberg, 1975). The presence of a double dissociation is important because it implies that different neurological structures underlie the different processing abilities (Young, 1998; although see Plaut, 1995 for a different view).

Neural Evidence

Single cell recording from the monkey's temporal cortex has revealed populations of cells which selectively respond to faces (Desimone, 1991; Perrett et al, 1992) reinforcing the idea of neural specialisation. Cell responses to non-face objects have been observed but these responses are less selective and are weaker in nature (Baylis, Rolls, Leonard, 1985). In humans, event related potentials (ERPs) recorded in the visual cortex show a face-specific response (N170) which peaks at around 170ms after a face is shown (Bentin, Allison, Puce, Perez, & McCarthy, 1996). Moreover, the so-called fusiform face area (FFA), which is a small region in the visual cortex, is particularly active when faces are being looked at compared to objects (Kanwisher, McDermott, & Chun, 1997) and responds more vigorously to full faces than to eyes alone (Tong, Nakayama, Moscovitch, Weinrib, & Kanwisher, 2000). Taken together, this provides compelling evidence that the processing of faces is 'special' compared with the processing of non-face objects, although the nature of this speciality remains controversial (e.g., Gauthier & Curby, 2005).

While the processing of the face seems to be specialised compared to the processing of non-face stimuli, other evidence suggests that different aspects of the face have, in turn, their own specialised processing routes. Behavioural evidence suggests a distinction between variant (e.g., expressions, eye gaze) and invariant (e.g., identity, gender) aspects of face processing (Bruce & Young, 1986). This distinction has been supported by neuroimaging work that has implicated different neural structures being involved in the processing of these two different aspects of face processing (Haxby, Hoffman, & Gobbini, 2000). For example, the lateral fusiform gyrus is thought to be involved in the processing of identity (an invariant aspect), whereas the superior temporal sulcus is thought to be involved in the processing of gaze direction (a variant aspect; Hoffman & Haxby, 2000).

The Processing of Specific Facial Signals

In the review of the face processing literature up to this point, an attempt has been made to highlight how the processing of faces differs from the processing of other objects, and hence, is in this sense, 'special'. I now move on to examine how specific facial signals[3] (in this case, eye gaze and emotional expression) are processed. In the following sections I will highlight the importance that both eye gaze and emotional facial expression have in terms of the signals they communicate, and their behavioural importance. I will also briefly review the evidence suggesting that the different signals have different neural substrates to decode them. I will consider eye gaze first, then emotional facial expressions, before reviewing what is known about how the processing of these two signals might interact. I then go on to look at what is known about the relationship between these signals and visual attention.

[3] Here I use the term 'facial signal' to refer to the role of the face in non-verbal communication.

Eye Gaze

The eye region of the face contains a potentially rich source of different types of visual information. Firstly, when eyes are directed towards you, this provides a powerful and fairly unambiguous signal that you are the focus of that person's attention. The signal can have a number of meanings, both positive and negative, depending on the context in which the signals are being sent and received. For example, if you happen to notice someone staring at you, one possible interpretation is that the person finds you attractive. This might be a good thing if the attraction is mutual, but not so good if it isn't. Regardless of the context, gaze directed at you constitutes a significant stimulus that is likely to require some modification in your own behaviour (e.g., either share or avoid the other person's gaze). In support of this, periods of mutual eye contact are associated with increases in galvanic skin response, a measure thought to index emotional arousal (Nichols & Champness, 1971).

Secondly, given that people generally look at things that are of interest to them, eyes directed away from you provide an important source of information about the location of potentially interesting items in the environment. From an evolutionary perspective the kinds of stimuli which would have been of most interest are those which relate to potential food, potential predators, and potential mates. As such, being able to follow gaze direction accurately could potentially confer an adaptive advantage over those without such skills (Emery, 2000).

Thirdly, it has been proposed that the ability to decode various signals from the eyes is the foundation for a 'mindreading system' (Baron-Cohen, 1995). In other words, observing someone else's gaze behaviour not only tells you about their direction of attention in relation to you and other agents in the external world, it also allows you to make inferences about the person's internal mental state (i.e., their thoughts, feelings, and intentions). This ability is crucial in being able to predict another person's behaviour through observation alone.

In line with the view that the detection of gaze direction is an important ability, we are able to detect very small deviations in gaze direction (Anstis, Mayhew, & Morley, 1969; Gibson & Pick, 1963). Furthermore, infants can distinguish between direct and averted gaze by the age of 2-3 months (Hains & Muir, 1996; Vecera & Johnson, 1995). There is also evidence that a preference to attend to the eye region of the face develops early. Maurer and Barrera (1981) recorded infants' looking times to schematic faces as a function of the amount of facial information being displayed. They found that infants spent the most time looking at the eye region with other parts (e.g., the mouth) getting much less attention. This suggests that the eye region is especially salient in terms of attracting attention in young infants.

Moreover, specific cells in the superior temporal sulcus (STS) of the macaque brain are known to be selective for gaze direction (Perrett, Smith, Potter, Mistlin, Head, Milner, & Jeeves, 1985). Lesions in these same cells produce impairments in the ability to discriminate gaze direction (Campbell, Heywood, Cowey, Regard, & Landis, 1990). Such neural specialisation has led some authors (Perrett, Hietanen, Oram, & Benson, 1992; Baron-Cohen, 1995) to suggest this represents the existence of a specific module that is specialised in detecting the direction of another's gaze. The evidence does underline the importance that is ascribed to the eye region of the face and in the specific ability to understand where another person is looking.

Thus, the eyes provide a range of information relevant to both the internal state of the person and external events in the world. Even very young infants pay particular attention to this region and at least some of the information it communicates is thought to be processed by a particular neural region (STS). I now move onto consider the processing of emotional facial expressions.

Emotional Facial Expressions

It has been suggested that emotional facial expressions evolved as an external representation of internal emotional states as a means for swift communication of these states between individuals (Blair, 2003). Darwin (1872/1998) believed that facial expressions are an innate and universal component of non-verbal communication. Compelling evidence supporting the universality of expression production has been put forward by Ekman (1972) who asked people from a preliterate culture in New Guinea to produce a facial expression in response to a number of potential scenarios (e.g., 'your friend has come and you are happy', 'you are angry and about to fight'). In each case, participants produced the same facial expressions as would be expected in Western cultures, strongly suggesting that expression production is universal and not dependent on cultural learning. In contrast, while identification of facial expressions from photographic images is consistently good for emotions such as disgust, anger, sadness, and happiness, it is less so for expressions of fear and surprise which are often confused for each other. This suggests that other cues such as context are important for an expression to be decoded correctly (Ekman, 1972).

In common with the processing of faces more generally, the processing of emotional expressions is disrupted by inversion (Prkachin, 2003) and by configural changes (Calder, Young, Keane, & Dean, 2000) suggesting they are processed in a holistic manner. However, as mentioned earlier, the processing of facial identity and facial expressions of emotion are considered to be conducted by functionally and anatomically independent systems (Bruce & Young, 1986; Posamentier & Abdi, 2003). This is supported by the presence of a double dissociation between facial identity and facial emotion processing. Prosopagnosics, who by definition cannot recognise familiar faces, can often still recognise emotion from facial expressions (Etcoff, 1984), while there are reports that some other brain-damaged participants can recognise identity but not facial expressions (Humphreys, Donnelly, & Riddoch, 1993).

This is not to say that there is a discrete neural system for processing all emotional expressions. For example, processing the facial expression of fear is thought to be carried out mainly by the amygdala (Adolphs, Tranel, Damasio, & Damasio, 1996; Le Doux, 1996; Young, Aggleton, Hellawell, Johnson, Broks, & Hanley, 1995), whereas the processing of the facial expression of disgust is considered to be performed by the basal ganglia and the insular cortex (Calder, Keane, Manes, Antoun, & Young, 2000; Sprengelmeyer, Rausch, Eysel, & Przuntek, 1998). Correspondingly, there are neuropsychological data which support this difference in processing. Patients with bilateral amygdala damage are particularly bad at perceiving fear (Adolphs, Tranel, Damasio, & Damasio, 1994) whereas patients with Huntington's disease (a degenerative disorder which initially affects the basal ganglia) are impaired at recognising disgust while the processing of other emotions remains relatively intact (Gray, Young, Barker, Curtis, & Gibson, 1997).

Furthermore, there is evidence that angry and sad facial expressions have dissociable neural responses (Blair, Morris, Frith, Perrett, & Dolan, 1999), with sad faces activating the left amygdala and right middle and inferior temporal gyrus, and angry faces activating the right orbitofrontal cortex and, bilaterally, the anterior cingulate cortex, but also thought to activate the amygdala (Adams, Gordon, Baird, Ambady, & Kleck, 2003). Unfortunately, Blair et al did not include fearful faces in their study so it is still unknown whether the observed response to sad faces in the amygdala is dissociable from that seen with fearful faces.

In contrast, research into the processing of happy facial expressions has shown no observations of consistent regional activation or any evidence of patients with a selective impairment in their processing (Posamentier & Abdi, 2003). Whilst this means less is known about how the facial expression of happiness is processed, it does indicate happy faces are processed differently from other expressions. This conclusion is reinforced by behavioural evidence suggesting that the recognition of happiness from the face occurs more accurately (Ekman & Friesen, 1976) and more quickly (Leppänen & Hietanen, 2002) than any of the other facial expressions.

Interaction between Gaze and Emotion Processing

As already discussed, when looking at another person's face, information extracted from the eye region can be particularly important, not least because it tells us whether we are of interest to that person. Similarly, extracting information about facial expression gives us knowledge about the person's internal emotional state. However, it is in the combination of the information from these two different sources that we gain a full understanding of the signals being communicated from a person's face (e.g., he is angry with me, she is scared at something over there). This section reviews work looking at how the interaction between gaze and emotion processing proceeds.

It is already well established (e.g., Bruce and Young, 1986) that the processing of certain facial characteristics, such as identity and emotion, proceeds independently (but see Schweinberger & Soukup, 1998). In a recent study, Ganel, Goshen-Gottstein, & Goodale (2005), investigated whether the same independence of processing observed for variant versus invariant aspects of the face could also apply to the perception of two variant aspects: emotion and gaze. In order to investigate this issue they used the Garner interference paradigm (Garner, 1974). This paradigm has two blocks: a baseline block and a filtering block. The baseline block involves the presentation of the stimuli as they vary along only one dimension (e.g., expression changes while gaze direction remains constant). The filtering block involves the presentation of the stimuli as they vary along both dimensions in a random order. In both blocks, participants have to make judgements about either expression (angry or happy) or gaze direction (direct or averted). If responses in the filtering block take longer than in the baseline block, it is reasoned that the processing of the dimension being measured is not done independently of the other dimension that is varying. Ganel et al found that the processing of facial expressions of emotion does not occur independently of the associated gaze direction. However, in contrast, the processing of gaze direction does occur independently of the associated facial expression.

This finding, that the perception of emotional facial expressions is modulated by gaze direction, is supported by neuroimaging evidence. Wicker, Perrett, Baron-Cohen, & Decety (2003) used positron emission tomography (PET) scanning to identify the neural structures involved in the processing of emotional facial expressions (angry and happy) as a function of observed gaze direction (either direct or averted gaze) They found that the anterior region of the superior temporal gyrus was active only when an observed emotion was directed at the viewer. However, despite showing that the processing of emotion is modulated by gaze direction, their analysis collapsed data across the two emotions. As such, it is not possible to conclude whether the pattern of activation differed as a function of the interaction between emotional expression and gaze direction.

Other recent work has addressed whether the relationship between gaze and facial expression depends on the type of signal each emotion communicates (i.e., whether there is an interaction between gaze and emotion processing). Adams and Kleck (2003) contended that in terms of behaviour, direct gaze, along with certain facial expressions (e.g., anger and happiness), are associated with an approach motivation. That is, they are most often seen in a context where the person adopting the expression will likely be approaching the viewer. Whereas, averted gaze, and other expressions (e.g., fear and sadness), are associated with an avoidance motivation. That is, the person adopting the expression will likely be avoiding the viewer. They asked participants to identify four facial expressions (anger, happiness, fear, and sadness) as a function of the associated gaze direction (direct or averted). In line with their predictions, they found that the identification of anger and happiness (the approach-oriented expressions) was fastest when they were seen with direct gaze. On the other hand, the identification of fear and sadness (the avoidance-oriented expressions) was fastest when they were seen with averted gaze.

Along similar lines, Adams et al (2003) looked at the processing of different emotional expressions (anger and fear) with either direct or averted gaze. Using functional magnetic resonance imaging (fMRI), they focussed their investigation on activation in the amygdala, which, as already discussed, is a neural structure thought to play a key role in the processing of fearful and angry faces, as well as threat-related stimuli more generally (Adolphs, Gosselin, Buchanan, Tranel, Schyns, & Damasio, 2005; Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Le Doux, Farb, & Ruggiero, 1990). They predicted that viewing emotional facial expressions with different gaze directions would modulate amygdala activation. Importantly, they predicted (in keeping with the Adams and Kleck (2003) behavioural study reported above) an interaction between gaze and emotion processing such that stimuli representing ambiguous danger (anger averted and fear direct) would result in greater amygdala activation than stimuli representing unambiguous danger (anger direct and fear averted). Their results supported this prediction.

These four studies clearly demonstrate that the processing of emotional facial expressions is modulated by the direction of gaze adopted by the face. In particular, the two studies from Adams and colleagues go a step further and indicate that both the ease with which a facial expression is processed, and the degree to which it activates appropriate neural regions, is dependent on the direction of observed gaze. This supports the finding that the perception of emotional facial expressions does not proceed independently from an analysis of gaze direction (Ganel et al, 2005). However, as Ganel et al demonstrated, the perception of gaze direction can proceed independently from the processing of emotional facial expressions.

To summarise thus far, there is compelling evidence that the processing of faces is 'special' compared with the processing of other kinds of visual stimuli. Furthermore, there is also evidence for the specialised processing of specific facial components and their related signals (i.e., gaze and emotion). I now move on to examine the relationship between face processing and visual attention before going on to look at the relationship between the processing of different facial signals and visual attention.

Face Processing and Attention

Given the evidence, reviewed above, that face processing is specialised compared with the processing of other kinds of stimuli, it would seem reasonable to predict that faces might be treated in a 'special' way by attention as well. However, initial attempts to compare the allocation of attention to faces with the allocation of attention to other classes of visual stimuli provided evidence against this view. Using a visual search task, Nothdurft (1993) asked participants to detect a schematic face target from an array of distractors. These distractors could be inverted or scrambled versions of the veridical face target. No evidence was found that attention was drawn to the target face on the basis of anything other than low-level stimulus properties (e.g., a v-shaped hair feature that was present in the stimulus). Similar negative results (i.e., no detection advantage for faces) were found by Brown, Huey, and Findlay (1997) using photographic facial images.

However, one problem with both of these studies is that the similarity between target and distractor items is very close. The more features the target shares with the distractor, the less likely it is that it will be found efficiently (Wolfe, 1998). In a recent study, Hershler and Hochstein (2005) asked participants to decide if a face was present or absent in arrays of colour photographs or schematic line drawings. Critically, the distracting stimuli in this experiment were a diverse set of images (see Figure 1.3). Under these conditions, Hershler and Hochstein (Exp1) reported very efficient search for the face targets with an increase in search time of only 6ms per additional distracting item. In contrast, efficient search was not observed when

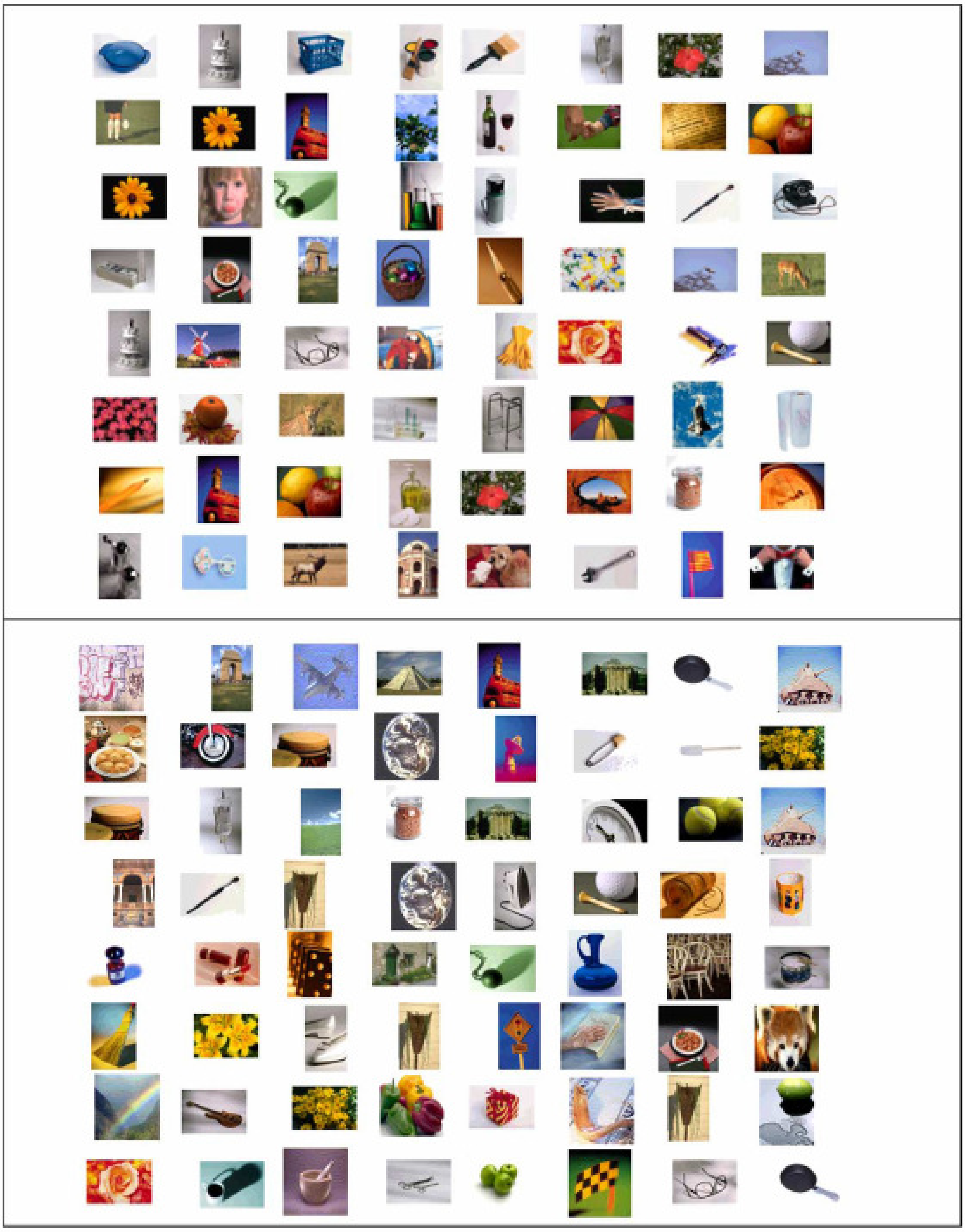

Figure 1.3: An example search array from Hershler and Hochstein (2005). When the task is to search for a face, attention is drawn quickly to the human face (top panel) but not the animal face (bottom panel).

the face stimuli were scrambled or when animal face stimuli were used as targets, with an increase of at least 20ms per additional item. This provides evidence against the possibility that the speeded search for the face target was due to a low-level perceptual feature of the original face stimuli (although see VanRullen, in press, for an alternative view). However, evidence of efficient processing of facial stimuli was only observed under conditions in which the face was relevant to the task, and as such, top-down influences on attention cannot be ruled out (Shiffrin & Schneider, 1977; Remington et al, 2001). In other words, this study shows that attention is drawn to a face when the task is to look for one. However, it does not tell us if a face will capture attention irrespective of its relevance to the task, or whether facial information is processed automatically.

Stronger evidence for stimulus-driven capture of attention by faces is available from other paradigms in which the face is always task-irrelevant. Jenkins, Lavie, and Driver (2003) asked participants to make a speeded semantic decision (pop star or politician) to a famous name presented at fixation while simultaneously ignoring a flanking photographic image of a famous face. The extent to which the flanking image interfered with task performance was observed in response latencies, with faster responses in congruent, compared with incongruent trials. Crucially though, these response latencies were measured as a function of the presence or absence of an additional distractor. This additional distractor could be an anonymous face, a phase-shifted face[4], an inverted face, or a meaningful non-face object (e.g., a fruit). Jenkins et al found that the additional anonymous face distractor ‘diluted’ (reduced) the amount of interference from the flanking famous face whereas the other stimuli had no such effect. In other words the amount of resources being

[4] Phase-shifted faces are created by randomly shifting the phase of the component spatial frequencies of each picture. The amplitude of the component spatial frequencies is shared in the original and phase-shifted version, as is overall brightness and size (Jenkins et al, 2003). Thus the phase-shifted faces are suitable controls for such low-level visual properties and do not contain any of the higher-level information possessed in faces.

allocated to the famous face (i.e., the one producing the congruency effect) was only reduced with the addition of another face. This supports the notion that, not only are task-irrelevant faces particularly difficult to ignore (i.e., attention is allocated to them automatically), there may be a capacity limit for face processing such that only one face can be processed at a time (Jenkins et al, 2003). I return to this issue in the latter part of Chapter 2. Regardless of the interpretation, these data suggest the relationship between face processing and attention is distinct from the relationship between attention and the processing of non-face stimuli.

There is also evidence that once attention has been allocated to a face it is particularly difficult to disengage it from that location. Bindemann, Burton, Hooge, Jenkins, & de Haan (in press) presented a variety of task-irrelevant stimuli at fixation (faces, inverted faces, fruit, or a blank) for 200ms. Superimposed on the stimuli was a green or red dot that corresponded respectively to a go or no-go signal. This was followed by the presentation of two lines in the periphery, one on the left and one on the right. One was vertical and the other was horizontal. On "go" trials, participants' task was to identify on which side the horizontal line appeared. On "no-go" trials the task was to press the space bar. On the critical "go" trials, responses to localise the target were significantly slower when the stimulus at fixation was a face compared with any of the other stimuli, thus suggesting the face was 'holding' attention at its location. However, one problem with this study is that responses on no-go trials (trials which required participants to press the space-bar) were also slower when the central stimulus was a face compared with the other stimuli. Bindemann et al interpret this favourably for their conclusions, suggesting this provides further support that the face is holding attention more effectively than the other stimuli. However, in the no-go trials, participants did not have to disengage their attention from anything in order to correctly complete the task; they responded to the signal on the face. This finding undermines the explanation that the observed differences are a result of being unable to disengage attention from the central face. Furthermore, even if their result does reflect an inability to disengage attention, it is not possible to conclude whether the face, per se, is responsible for the effect or whether it is a function of gaze being directed at the viewer (see next section). Further investigation is needed to clarify this point

This aside, these behavioural data generally lend weight to the notion that the 'special nature' of face processing extends to the domain of attention. One final piece of neuropsychological evidence makes the case even more firmly. Vuilleumier (2000) tested three patients with left spatial neglect and visual extinction[5] from right brain damage on their ability to identify briefly presented pictures of faces, names, or meaningless shapes in the left, right, or both visual hemi-fields. When the stimuli were presented bilaterally, patients failed to identify the words or the shapes far more often than the faces. Furthermore, they failed to identify a right-side shape far more when it was accompanied by a left-side face compared with a left-side name. This indicates that faces are privileged in overcoming extinction and, thus, they capture attention in the sense that they are more readily detected than other stimuli.

To summarise so far, there is converging evidence that the processing of faces is 'special' compared with the processing of other objects. This evidence comes from

[5] Spatial neglect and visual extinction are disorders of attention associated with damage to the right parietal lobe. They are both characterised by a tendency to not report stimuli presented to their contralesional side when they are presented simultaneously with stimuli on the ipsilesional side. This is despite being able to report stimuli on either side if they are presented alone.

behavioural studies showing how the perception of faces proceeds differently from object processing (e.g., inversion effects) as well as neuropsychological and neural investigations providing compelling evidence for the neuroanatomical independence of face processing. This 'special' processing extends to the domain of selective attention where evidence suggests that faces are associated with a processing bias such that when a face is present in the visual field, attention is drawn to its location, and once there, is relatively difficult to disengage. I now move on to look at the relationship between different facial signals and visual attention. I first consider signals related to eye gaze before going on to look at those related to emotion.

<u>Eye Gaze and Attention</u>

As already discussed, when someone looks directly at you, this represents a significant event with potential consequences for your own behaviour. Given this significance, initial investigations into the relationship between eye gaze and attention focussed on whether gaze directed at you draws attention to its location faster than gaze looking away. To address this question von Grünau and Anston (1995) used a visual search task in which participants had to search for a pair of eyes with direct gaze amongst averted gaze distractors, or search for a pair of eyes with averted gaze amongst direct gaze distractors. They demonstrated that eyes with direct gaze were identified more quickly as targets compared to eyes with averted gaze. However, their experiment (and a subsequent replication by Senju, Hasegawa, & Tojo, 2005) had a critical confound; they did not equate the distractors through which search had to be performed. Recent work has suggested that once allocated to a face with direct gaze, it is harder to disengage attention from this location compared to locations occupied by faces with averted gaze or closed eyes (Senju & Hasegawa, 2005). Thus, in von Grünau and Anston's experiment, the apparent ease with which targets are detected when they are eye pairs with direct gaze may not be due to direct gaze drawing attention to its location. Rather, the search asymmetry could be due to faster search through averted gaze distractors compared to search through direct gaze distractors. Some very recent work supports this alternative conclusion (Cooper, Law, & Langton, in preparation). If this conclusion is correct, it still suggests that attention prioritises the processing of direct gaze, but in the sense that attention is <u>held</u> at its location and not in the sense that it is drawn to its location. This distinction is important because if attention is drawn to the location of direct gaze, this implies preattentive processing of the relevant stimulus features (Wolfe, 1998), whereas, attention being held by direct gaze suggests a postattentive mechanism is responsible.

While such evidence supports the notion that direct gaze might have a 'special' relationship with attention, it only does so in the context where the gaze direction is task-relevant. As such, in common with the experiments (discussed earlier) using the visual search task to investigate the allocation of attention to faces more generally, the extent to which this effect is independent of top-down processing can not be established using this task. I return to this issue in Chapters 2 and 4.

Senju and Hasegawa's (2005) finding that direct gaze holds attention also suggests an alternative interpretation to Bindemann et al's (in press) conclusions that faces hold attention. Senju and Hasegawa measured responses to peripheral targets as a function of faces with different gaze directions presented at fixation (in a similar way to Bindemann et al, in press, discussed above). These faces could be looking at the participant, looking away, or have eyes closed. Response times to respond to the target were slowed in the condition in which the eyes were directed at the participant. This suggests that it is particularly difficult to disengage attention from eyes looking at you. In Bindemann et al's study the gaze of the face was always directed at the viewer. Given Senju and Hasegawa's finding that it is particularly difficult to disengage from direct gaze, it may be that it is not the face per se that holds attention; rather the eyes are the most important feature in this regard.

The evidence showing that observing a shift in another's gaze creates an automatic, corresponding shift in our own attention (Friesen & Kingstone, 1998; Driver et al, 1999; Langton and Bruce, 1999) has already been discussed. This is very powerful evidence for the importance of the relationship between gaze and attention. However, eye gaze may not be unique in this respect. Similar cueing effects have been demonstrated from the presentation of arrows (Tipples, 2002) which suggests that eye gaze may not be entirely special as has been argued. Importantly though, covert attentional shifts[6] in response to gaze cues have been reported in infants as young as 10 weeks (Hood, Willen & Driver, 1998), and by the age of 4-6 months, babies will follow the direction of their mother's gaze (Scaife & Bruner, 1975). This suggests that gaze following is a fundamental visuomotor behaviour with at least some of the relevant neural architecture being innate. Similar effects in infants have never been observed with arrows. Correspondingly, Baron-Cohen (1995) has suggested humans are equipped with an eye-detection detector (EDD); a cognitive module with the function of, amongst other things, detecting the presence of eyes in the environment and computing their gaze direction.

[6] Covert attention refers to attention that can move independently of eye movements. In contrast, eye movements are often referred to as signals of overt attention.

While the power of another's gaze direction to shift our own attention is clear, it is not clear whether such effects occur when they are independent of task demands. This is because in a standard cueing paradigm (e.g., Langton & Bruce, 1999) the possible target locations are always relevant to the task, even when the predictive nature of the cue is minimal. This leaves open the question as to whether shifts in attention in response to averted gaze cues will still occur when they are entirely task-irrelevant. I return to this issue in Chapter 3.

In summary, the ability to detect and decode the direction of someone else's gaze is of fundamental importance to us. Gaze directed at us indicates we are of interest to that person and results in increased emotional arousal and a difficulty to disengage attention from its location. On the other hand, gaze directed elsewhere in the environment indicates the location of items of potential interest and viewing such behaviour in another's attention results in corresponding shifts in our own attention. I now move on to consider the relationship between emotional facial expressions and attention.

<u>Emotional Facial Expressions and Attention</u>

Much of the work looking at the relationship between emotional facial expressions and attention has focussed on angry facial expressions and how the allocation of attention to this expression differs from the allocation of attention to the other expressions. The assumption underlying this work is that angry facial expressions signal threat. Therefore, possession of the ability to identify threat rapidly in the immediate environment would be, in evolutionary terms, advantageous (e.g., Öhman, 2002; Le Doux, 1996). While this hypothesis seems intuitively plausible, it has received mixed support. Hansen and Hansen (1988) carried out the first empirical investigation into this issue. Using a visual search task, participants had to search through arrays of faces and decide if the faces were all the same or if there was one different. They found that response times to identify the presence of a ‘different’ face from an array of neutral distractors were faster when the discrepant face had an angry expression compared with when the expression was happy. They concluded that this provided a demonstration that attention was preferentially drawn to the location of the angry face, and hence, the location of potential threat. However, a subsequent analysis of the stimuli used in Hansen and Hansen’s study revealed that the speeded detection of the angry faces was due to the presence of a contrast artefact in the photographic images. The removal of this artefact was associated with the disappearance of the previously observed speeded detection of the angry faces (Purcell, Stewart, & Skov, 1996).

A number of more recent attempts to investigate the relationship between emotional facial expressions and attention using the visual search task have tried to avoid the occurrence of perceptual artefacts by employing schematic stimuli (Öhman, Lundqvist, and Esteves, 2001; Fox Lester, Russo, Bowles, Pichler, & Dutton, 2000, Eastwood, Smilek, & Merikle, 2001) . These stimuli are stereotypic examples of target expressions which are constructed using different configurations of the same facial features. They offer advantages over the use of photographic images because they can be more closely controlled for contrast artefacts and other low-level perceptual confounds like those identified by Purcell et al (1996). Öhman et al (2001) replicated Hansen and Hansen’s original experiment with these new stimuli and found, like Hansen and Hansen, a discrepant face was detected more quickly when it was angry compared with when it was happy. Similar findings from another experiment using the visual search task with schematic emotional faces have also been reported (Fox et al, 2000). These results support the conclusion that angry faces are prioritised for processing above other expressions. However, these data are obtained under conditions in which the faces are task-relevant. As discussed above this leaves open the possibility that these effects are driven by top-down processing, and are not stimulus-driven as has been proposed (e.g., Öhman et al, 2001). Under conditions in which the stimuli are not relevant to the task, the data overwhelmingly suggests that biases towards threat-related stimuli more generally (including angry faces) are only present in individuals who are highly anxious[7] (Mogg & Bradley, 1999; Mogg, Bradley, De Bono, & Painter, 1997; Bradley, Mogg, Falla, & Hamilton, 1998; Fox, 2002; Koster, Crombez, Verschuere, & De Houwer, 2004; although see Wilson & Macleod, 2003). I return to this issue in Chapters 4 and 5.

Other evidence from patients suffering with spatial neglect and visual extinction questions the apparent superior ability of angry faces to capture attention. As described above, these patients will often not report seeing stimuli presented to the visual field contralateral to their lesion if the stimuli are presented alongside another which is on the ipsilesional side. Corresponding to the findings of Vuilleumier (2000), further investigations by Vuilleumier and Schwartz (2001) and Fox (2002) found that faces were less likely to be extinguished than non-face objects (e.g., fruit). Furthermore, they found that faces with emotional (angry and happy) expressions were less likely to be extinguished than faces with neutral expressions. Interestingly though, both types of emotional face were detected with the same frequency. This suggests that facial signals of emotion are prioritised for processing in the sense that they overcome extinction. However, unlike the results

[7] Anxiety-prone individuals are thought to be hyper-vigilant to threat-related stimuli (Mogg & Bradley, 1999).

from the visual search task, the data from these patients suggests that the valence of the facial expression does not influence the allocation of attention.

While this suggests an apparent contradiction between the results from the visual search task and those from the neglect patients, it is difficult to compare results from these two sets of studies directly because their measures differ in sensitivity. For example, both the visual search task and the study with the neglect patients require participants to identify a target. Thus, both have an accuracy measure. However, additional to this, the visual search task reveals how long it takes for the target to be identified and, thus, can potentially reveal differences that could not be seen if accuracy is the only measure. Therefore, if there was a difference to be found between the processing of the two types of emotional expression, the visual search task would be more likely to find it. Accordingly, the results from the neglect patients do not challenge those from the visual search task. However, to examine further the nature of emotional expression processing in neglect patients, a future experiment could measure the extent to which extinguished faces are later remembered as a function of their emotional expression (c.f. Vuilleumier, Schwartz, Clarke, Husain, & Driver, 2002). This approach would have the benefit of being able to replicate the previous work, as well as providing an implicit, and therefore, more sensitive measure of the extent to which each emotional expression is processed.

Overall, these data show that angry faces are selected for attention more rapidly than happy faces but both are equally likely to overcome extinction. The visual search data is subject to the caveat that the targets in this paradigm are always task-relevant and, as such, these data do not help determine whether these effects are independent of task demands. I now move on to consider the interaction between attention and the processing of both gaze direction and emotional facial expressions.

Gaze Direction, Emotional Facial Expressions, and Attention

Given the evidence already reviewed, there are two key questions involving the interaction between gaze direction, emotional facial expression, and attention. The first question is whether shifts in attention in response to observing another's averted eye gaze are modulated by the associated emotional expression. For example, are you more likely to follow a shift in someone's gaze if they have a fearful expression compared with a neutral one? The second question is the reverse of this; whether shifts in attention in response to another's emotional expression are modulated by the associated gaze direction. For example, is your attention more likely to be captured by an angry face if it is looking at you compared to looking somewhere else?

In response to the first question there have been a number of studies to date. Yoshikawa and Sato (2001) modified a standard gaze-cueing paradigm by varying the expression that the centrally presented face could adopt (e.g., surprised, angry, happy, and neutral). In common with previous work (e.g., Langton & Bruce, 1999), they found that response times to localise the target were faster in cued trials compared with uncued trials. Furthermore, they found that responses on cued trials were speeded when the face had a surprised expression, and responses in uncued trials were slowed when the face had an angry expression. This shows that the allocation of attention in response to gaze cues is modulated by the emotional expression on the face and implies that information from the two sources is integrated before attention is allocated to the scene.

Two subsequent attempts to address this issue have provided only equivocal support for this position. Mathews, Fox, Yiend, & Calder (2003) compared cueing effects found from faces with either neutral or fearful expressions. They reasoned that a face signalling the presence of fear somewhere in the environment should produce the most powerful cueing effect. However, whilst consistent cueing effects were found from both face types, an increase in the magnitude of the observed cueing effect in response to fearful faces was only seen with anxious individuals. Hietanen and Leppänen (2003) examined gaze cueing effects as a function of the central face having a neutral, happy, angry, or fearful expression. Despite finding reliable cueing effects across six experiments, they did not find any modulation of these effects attributable to the emotional expression of the central face.

With the exception of Yoshikawa and Sato's (2001) data pertaining to the expression of surprise, these experiments are consistent with Ganel et al's (2005) findings that the processing of gaze proceeds independently from the processing of emotion. The reason that Yoshikawa and Sato's findings seem inconsistent with this interpretation could be because in their experiment, the head direction was consistent with the eye direction, meaning participants received cueing information from the whole face rather than just the eyes as they did in the two other studies. Consequently, from these studies there is some evidence that information about direction of attention (as indexed by head direction) and emotional expression are combined to allocate attentional resources in the environment. However, there is no convincing evidence that this is done through integrating information about eye gaze.

In response to the second question that was posed at the beginning of this section concerning whether the allocation of attention to various emotional expressions will vary as a function of gaze direction, there are currently no published studies which address this issue. I investigate this question in Chapter 4 by examining the allocation of attention to different facial expressions (neutral, angry, happy, and fearful) with either direct or averted gaze.

Thesis Overview

As already discussed, evidence for stimulus-driven shifts in attention comes mainly from studies looking at abrupt onsets (e.g., Yantis & Jonides, 1984; Posner 1980; Franconeri et al, 2004). It is assumed that these stimuli are prioritised for processing by attention because they represent potentially significant events in the environment (e.g., the arrival of a predator). Faces are arguably one of the most significant stimuli we encounter on a regular basis and correspondingly, recent work has suggested that the processing of faces may also receive priority from attention (e.g., Jenkins et al, 2003). However, what is less well understood is the relationship between attention and the various signals which a face can communicate. For example, there is evidence that direct gaze will attract attention if the task is to search for it (von Grünau & Anston, 1995; Senju, Hasegawa, & Tojo, 2005). Similarly, once eye contact has been established, it is particularly difficult to disengage attention from those eyes (Senju & Hasegawa, 2005). However, it is not known whether direct gaze is particularly difficult to ignore. This issue is addressed in Chapter 2 by using a response competition paradigm to assess the extent to which direct gaze stimuli can be ignored.

There is strong evidence that observing another's averted gaze (a facial signal which potentially communicates the presence of 'interesting items' in the environment) creates corresponding shifts in the viewer's attention (Friesen & Kingstone, 1998; Driver et al 1999; Langton & Bruce, 1999). It is thought that these shifts are reflexive and, as such, not under top-down control. However, the extant data on this topic is based on the gaze-cueing paradigm. In this paradigm, the presented gaze always has some correspondence to the potential location of the target's appearance (i.e., the gaze cue sometimes predicts the location of the target). This being the case, it is not possible to make strong claims that the observed effects are entirely stimulus driven. This issue is addressed in Chapter 3 by means of recognition memory paradigm which compares incidental memory for gazed-at and non gazed-at items that are entirely irrelevant to the participants' task.

Another type of signal communicated by the face is that of emotion. Much of the work examining the relationship between emotional facial expressions and attention has focussed on the expression of anger (e.g., Öhman et al, 2001). This is because it is assumed that attention might preferentially orient to threatening items in the visual field (i.e., an angry face). Largely, the evidence supports this position (Öhman et al, 2001; Fox et al, 2001; although see Hunt, Cooper, Hungr, & Kingstone, in press). However, the stimuli are always presented with gaze directed at the viewer. This does not allow any understanding concerning precisely why attention is drawn to the location of the angry face. It is not known whether attention is drawn to the face because it is displaying an emotion per se, or whether attention is drawn to the face because it is directing an emotional display towards the viewer. This point is made particularly salient by Ganel et al's (2005) study which demonstrated cues from gaze can be processed independently from those of emotion; however, emotional expressions can not be processed independently of gaze direction. Thus gaze direction is very important in the processing of facial displays of emotion and may influence how attention is allocated to them.

I address these issues in Chapter 4 by looking at the relationship between emotion, eye gaze, and attention using a dot-probe task. This paradigm measures the allocation of attention to task-irrelevant stimuli. The experiments in Chapter 4 represent the first attempt to study the allocation of attention in response to facial stimuli which vary as a function of both gaze and emotion. In Chapter 5 I take this issue further by looking at how the relationship between gaze, emotion, and attention is influenced by individual differences in anxiety. One characteristic of those high in anxiety is thought to be a hyper-vigilance to threat-related stimuli (including angry expressions) (e.g., Mogg & Bradley, 1998). As such, studying the allocation of attention to threat-related facial signals in a population with different levels of anxiety will allow more insight into the individual differences in the processing of those signals.

Together, the experiments in this thesis represent an attempt to understand more fully the relationship between meaningful facial signals and visual attention. This is an area that has been historically overlooked in the investigation of visual attention. They focus on the role that eye gaze has in the allocation of attention to faces, both when they are free from expression and when they express emotion. Given that such signals are so regularly encountered, their study will help illuminate the processes by which attention operates in the ‘real world’ more generally. This work also serves to highlight the need for general theories of visual attention to incorporate such data. To not do so fundamentally risks misrepresenting the nature of attention as it operates out-with the laboratory setting.

Chapter 2

Effects of distractor congruency on gaze processing

As a first step in the study of the interaction between attention and eye gaze, the current chapter uses an interference paradigm to assess whether direct gaze is particularly difficult to ignore. As discussed in Chapter 1, the direction of another's eye gaze is a rich source of visual information. Not only does it provide information about that person's direction of attention in relation to the viewer and other agents in the external world, it also allows inferences to be made about the person's internal mental state (i.e., their thoughts, feelings, and intentions). This ability is crucial in being able to predict another person's behaviour through observation alone (Baron-Cohen, 1995).

When a person's gaze is directed towards you, regardless of the specific intent, a fairly unambiguous message is sent that the person is interested in you. In evolutionary terms, it would be useful to be able to identify quickly when someone is looking at you since this potentially signals that you are the object of that person's ire or desire. Indeed, there is evidence that the processing of gaze directed at you (i.e., direct gaze) is prioritised over gaze that is directed elsewhere (i.e., averted gaze) (von Grünau and Anston, 1995; Senju et al, 2005; Senju & Hasegawa, 2005; although see Chapter 4, this thesis). Furthermore, once mutual eye contact has been achieved, there are implications for physiological arousal. Mutual eye contact has been associated with increases in heart and breathing rate, as well as increases in galvanic skin response (Nichols & Champness, 1971; Gale, Nissim, Lucas, & Harpham, 1972). Added to this, mutual eye contact can be perceived as a sign of friendship or liking (Kleinke, 1986) or as a threat-signal

(Ellsworth & Carlsmith, 1973), depending on the context. Given the importance ascribed to another person looking directly at you, both in terms of social significance, and the allocation of processing resources, it may be that direct gaze is particularly difficult to ignore, even when purposefully trying to ignore it.

The extent to which task-irrelevant information can be ignored is a fundamental question in the study of selective visual attention. Using a distractor interference paradigm, in which flanking distractors can either be congruent or incongruent with a centrally presented item, the degree of distractor processing can be measured as a function of the latency to respond to a feature of the central item. For example, the task could be to make a semantic decision about a centrally presented word (e.g., is it animate or inanimate?) while trying to ignore the flanking words which could either be congruent or incongruent with the semantic category of the central item. The rationale of this paradigm is that if the flanking distractors cannot be ignored, latency to respond to the central target will be longer when the distractors are incongruent with the target compared to when they are congruent. Such distractor interference effects have been reported to occur with a range of target-distractor pairs (e.g., letter-letter, Eriksen & Eriksen, 1974; picture-word, Smith & MaGee, 1980).

Accordingly, the following three experiments make use of this paradigm to investigate whether direct gaze is particularly difficult to ignore. No evidence is found to support this position. However, all three experiments do indicate that facial information from more than one source can be processed simultaneously, an idea that runs counter to the notion of strict capacity limits in face processing (Bindemann, Burton, & Jenkins, 2005). This issue is addressed further in Experiment 4.

Experiment 1

Experiment 1 presented participants with a pair of eyes in the centre of the screen and asked them to decide whether those eyes were open or closed. Meanwhile, this central eye pair was flanked by two sets of distractor eyes which participants were instructed to ignore. These task-irrelevant distractors could be either congruent or incongruent with the task-relevant pair. It was predicted that responses made during congruent trials would be quicker than those made during incongruent trials (i.e., congruency effect). However, it was also predicted that this congruency effect would be more pronounced when the distractors had direct gaze compared with closed eyes (i.e., they would be particularly difficult to ignore).

Method

Participants – Sixteen undergraduate psychology students (12 female, with a mean age of 20.5 years) from the University of Stirling took part for course credit.

Materials and Apparatus – Photographs were taken of four individuals (two males) using an Olympus C-900 digital camera with eyes looking at the camera or eyes closed. These photographs were cropped to show only the eye region of the face (including eyebrows) and measured 0.64˚ in height with width being no less than 1.7˚ and no greater than 1.9˚ of visual angle. Three of the four eye pairs were positioned in a column (i.e., one on top of the other) with 0.9˚ of visual angle separating the centre of the stimuli (see Figure 2.1). Stimuli were presented on a Tatung 17” monitor with a Viglen PC with a Pentium III processor using E-prime software. Responses were collected on a serial response box (Psychology Software Tools, model # 200A).

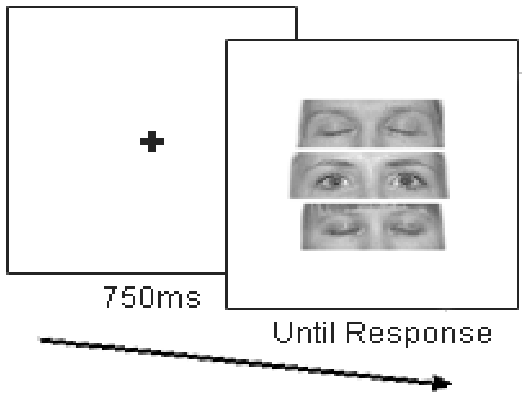

Figure 2.1: An example of Experiment 1 procedure. Participants responded to the face in the centre (decide if the eyes are open or closed) while trying to ignore the flanking faces. A trial from the incongruent condition is shown.

Design and Procedure – A 2x2 within-participants design was used. The factors were gaze (eye open or eyes closed) and distractor congruency with central target (congruent or incongruent). Participants were seated 80cm from the screen with viewing distance kept constant by means of a chin rest. Each trial began with a fixation cross in the centre of the screen for 750ms followed by the presentation of three eye pairs. Participants had to decide if the eyes of the most central eye pair were open or closed by pressing the right-most response key if the eyes were open and the left-most key if the eyes were closed. Key assignment was counter-balanced across participants. Eight practice trials were followed by 96 experimental trials, 24 in each of the four experimental conditions.

Results

The interparticipant mean of each participant's median correct response time for each experimental condition is displayed in Figure 2.2. As can be seen in Figure 2.2, responses made during incongruent trials were slower than those made during congruent trials. However, the magnitude of the effect was similar for both targets. These data were analysed using a 2 (central gaze open or closed) x 2 (distractors

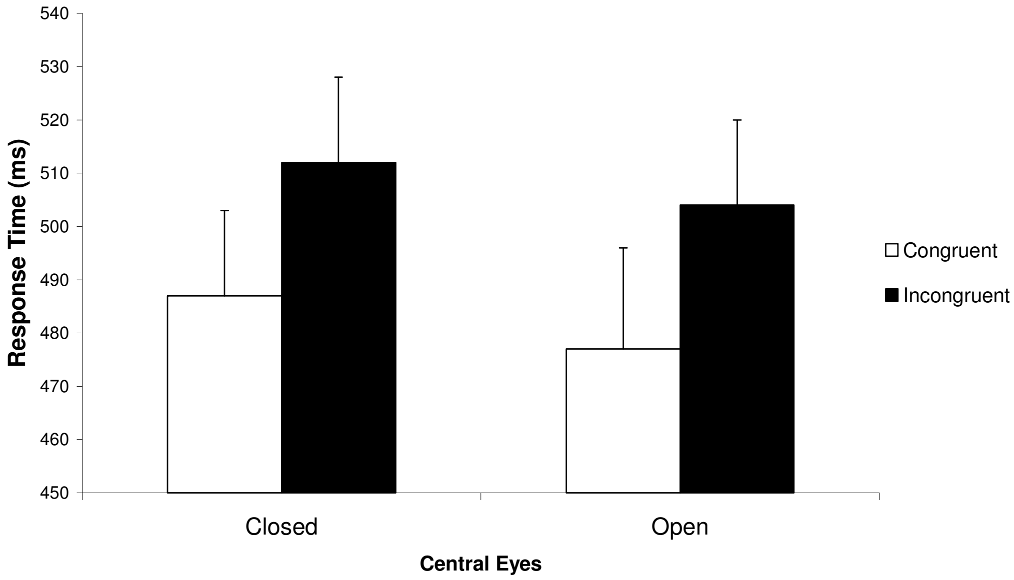

Figure 2.2: Response time (ms) to decide if centrally displayed eyes are open or closed while flanking eyes are congruent or incongruent.

congruent or incongruent) repeated measures ANOVA. Confirming the observations from Figure 2.2, responses in trials where the gaze of the distractors was incongruent with the gaze of the central eye pair were significantly slower than when the distractors were congruent with the central eye pair, $F(1,15) = 13.07$, $p = .003$. Neither the main effect of central gaze state (open or closed) nor the interaction with congruency were significant (both ps >.18). Trials with errors were rare (2% of data) and were 3 times more likely in the incongruent condition (1.5%) than the congruent condition (0.5%). No further analysis of errors was conducted.

Discussion

The results from Experiment 1 clearly show that decisions concerning the eye gaze status of the central eye pair could not be made without processing the flanking eye pairs. This can be seen in the highly significant congruency effect. In contrast, these results do not lend any weight to the notion that eyes looking at you are particularly difficult to ignore. In this experiment, closed eyes were just as difficult to ignore as eyes directed at the viewer, as indexed by the similar magnitude of interference they produced. Given the evidence that direct gaze is particularly salient, both in social terms and in the allocation of resources for their processing, this result is somewhat surprising. However, one potential criticism of Experiment 1 is that both the flankers and targets remained on the screen until participants responded. This gives ample opportunity for participants to process all the stimuli in a serial fashion and thus any extra processing that is afforded to the direct gaze stimuli might be masked. To address this problem, Experiment 2 presented the same stimuli from Experiment 1 but now only showed them for 200ms.

Experiment 2

Method

Participants – Sixteen undergraduate psychology students (13 female, with a mean age of 20 years) from the University of Stirling took part for course credit. None had taken part in Experiment 1.

Materials and Apparatus – These were identical to Experiment 1.

Design and Procedure – This was identical to Experiment 1 except the stimuli were only presented for 200ms. Stimulus presentation was followed by a blank screen that remained until participants responded.

Results

The interparticipant mean of each participant's median correct response time for each experimental condition is displayed in Figure 2.3. As can be seen in Figure 2.3, responses made during incongruent trials were slower than those made during congruent trials. Again, the magnitude of the effect was similar for both targets. These data were analysed using a 2 x 2 repeated measures ANOVA. Confirming

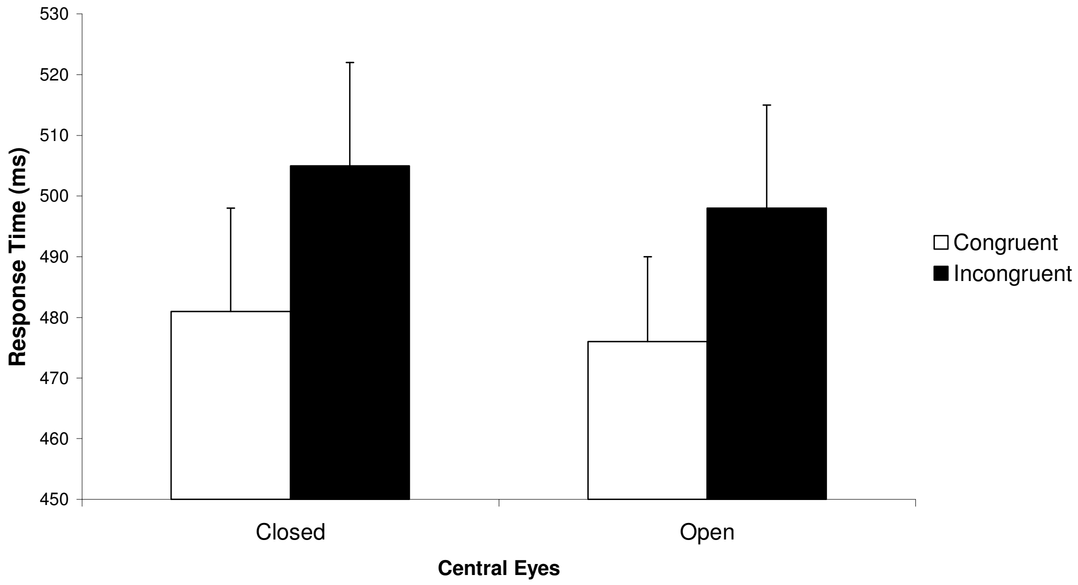

Figure 2.3: Response time (ms) to decide if centrally placed eyes are open or closed while flanking eyes are congruent or incongruent using a 200ms presentation time.

the observations from Figure 2.3, responses in trials where the gaze of the distractors was incongruent with the gaze of the central eye pair were significantly slower than when the distractors were congruent with the central eye pair, $F(1,15) = 21.74$, $p<.001$. Neither the main effect of central gaze state (open or closed), nor the interaction with congruency were significant (both ps >.3). Trials with errors were rare (3.9% of trials) but were twice as likely to occur during incongruent trials (2.6%) than during congruent trials (1.3%). No further analysis of errors was conducted.

Discussion

The results from Experiment 2 very closely mirror those of Experiment 1. There were clear distractor interference effects but no suggestion that eyes with direct gaze are particularly difficult to ignore. However, given that the stimuli were presented for a relatively brief period of time (200ms), and given that they were physically close (within 1˚ of visual angle) it could be that participants experienced

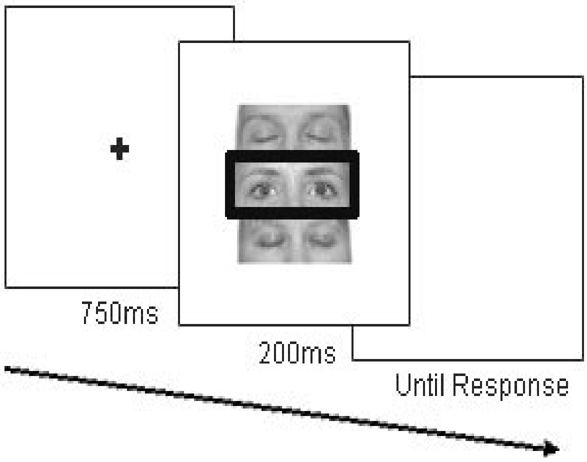

Figure 2.4: An example of Experiment 3 procedure in which a black box was added around the central eye pair in an attempt to aid participants to attend only to the central eye pair. Participants responded to the face in the centre (decide if the eyes are open or closed) while trying to ignore the flanking faces. A trial from the incongruent condition is shown.

a degree of spatial uncertainty regarding which of the stimuli to respond to (Levi, Klein, & Yap, 1987). Again, this could be masking any priority that direct gaze eyes receive when they are being processed. To help rule out this possibility, Experiment 3 enclosed the to-be-attended stimulus inside a black frame. This served to delineate the target from the distractors.

Experiment 3

Method

Participants – Thirteen undergraduate psychology students (nine female, with a mean age of 20 years) from the University of Stirling took part for course credit. None had taken part in Experiments 1 or 2.

Materials and Apparatus – These were identical to Experiment 2 except a black box was placed around the central pair of eyes (see Figure 2.4) in order to reduce the degree of spatial uncertainty regarding which eye pair was task relevant.

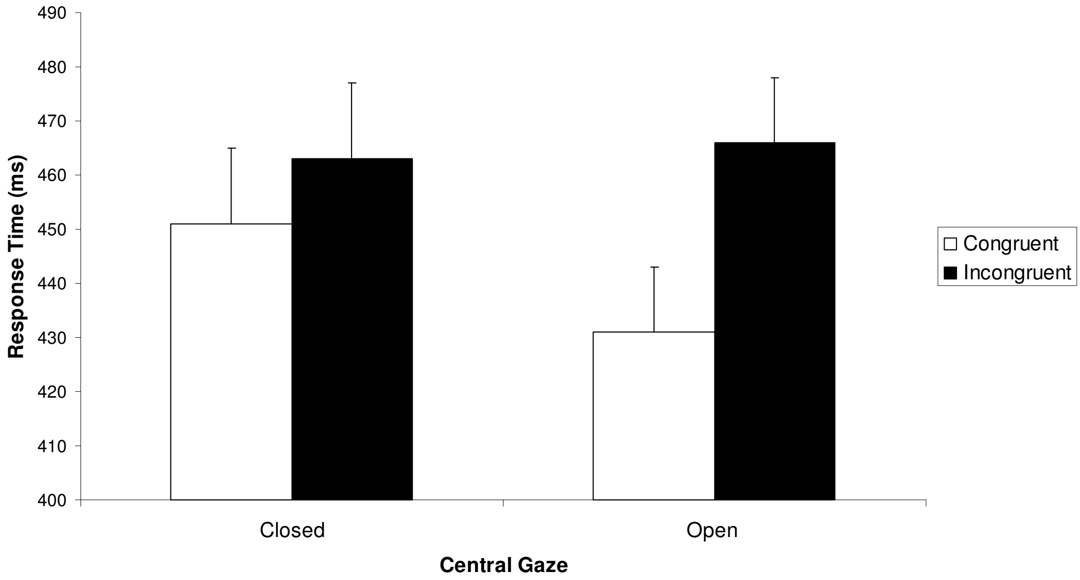

Figure 2.5: Response time (ms) to decide if centrally placed eyes are open or closed while flanking eyes are congruent or incongruent using a 200ms presentation time. A black box was placed around the central eye pair to help ensure participants attend only to this eye pair.

Design and Procedure – This was identical to Experiment 2 except it was made clear that participants should only attend to the eye pair that was inside the black box.

Results

The interparticipant mean of each participant's median correct response time for each experimental condition is displayed in Figure 2.5. As can be seen in this figure, responses made during incongruent trials were slower than those made during congruent trials. There also appears to be more interference from closed eye distractors compared with open eye distractors. This seems to be due to slower RTs for congruent closed eyes compared with open eyes. These data were analysed using a 2 (central gaze open or closed) x 2 (distractors congruent or incongruent) repeated measure ANOVA. Confirming the observations from Figure

2.5, responses in trials in which the gaze of the distractors was incongruent with the gaze of the central eye pair were significantly slower than when the distractors were congruent with the central eye pair, $F(1,12) = 14.89$, $p=.002$. Furthermore, there was a marginally significant main effect of central gaze state (open or closed), $F(1,12) = 4.57$, $p = .054$, reflecting faster overall response times when the central eyes were open compared with when they were closed. However, the interaction between congruency and eye status that these data suggest, did not reach significance ($p>.15$). Trials with errors were rare (5% of trials) and were more likely to occur during incongruent trials (3%) than during congruent trials (2%). No further analysis of errors was conducted.

Discussion

The addition of the black frame around the central eye pair seems to have decreased the degree of spatial uncertainty in the task compared with the previous two experiments. This is supported by the fact that responses in Experiment 3 were approximately 40ms faster on average than those in Experiments 1 and 2, suggesting that the task became easier with the addition of the box (Donders, 1969/1868). However, despite this, results from Experiment 3 follow the pattern of data observed in Experiments 1 and 2. Responses made during incongruent trials were once again slower than those made during congruent trials. However, again there was no evidence that direct gaze is particularly difficult to ignore.

Somewhat surprisingly, there was a marginally significant effect of eye gaze such that responses were generally faster when the central eyes were open compared to when they were closed. Closer inspection of the data from Experiments 1 and 2 reveal that a similar pattern is present there as well, albeit not significant. The faster responding in the direct gaze condition could be a function of the heightened autonomic arousal that is associated with direct eye contact (Nichols & Champness, 1971). Further research is needed to address this possibility.

Across the previous three experiments in this chapter, distracting eye stimuli have been shown to interfere with the processing of the central eye pair. However, these have also failed to show any evidence that direct gaze eyes are particularly difficult to ignore. It is possible that the failure to find this predicted effect was due to the contrived nature of the stimulus presentation (i.e., 2-dimensional and static) compared with how gaze is seen in the 'real world' (i.e., 3-dimensional and dynamic). Indeed, it is known that the medium in which people interact influences the nature of the interaction. For example, different patterns of gaze behaviour are shown in face-to-face interactions compared with those mediated by a video-link (Doherty-Sneddon, Anderson, O'Malley, Langton, Garrod, & Bruce, 1997). As such, it may be that specific rules of interaction apply between two individuals who are face-to-face that do not apply under other circumstances. Given that there is no potential for interaction between the participant and the photograph in any true sense, the direct gaze stimuli do not hold the same significance. Therefore the results in Experiments 1 – 3 may have been in line with predictions if real faces had been used in place of photographs.

However, while this may seem like a plausible explanation for the current results, it does not explain why other studies looking at the allocation of attention to eye stimuli have found differential effects of gaze direction, even when using simple schematic stimuli. For example, von Grünau and Anston (1995) used a visual search task with schematic eye-like stimuli in which participants had to search for either direct or averted gaze stimuli amongst distractors. Despite using these impoverished stimuli, they reported that direct gaze targets were found more quickly than averted gaze targets.

Given that such results have been found with this type of stimuli in a visual search task, it is possible that differences in task demands might account for the inability to support the hypothesis in the current experiment that direct gaze would be particularly difficult to ignore. In their experiment, von Grünau and Anston's stimuli were task-relevant. Participants had to look for a specific target (direct or averted gaze) amongst a background of distractors. Under these conditions, direct gaze drew attention to its location. However, in the current experiment, the participants' task was specifically to ignore the flanking stimuli and only respond to those stimuli in the centre. Under these conditions, no extra resources were allocated to the direct gaze stimuli. This suggests that the allocation of attention to eye stimuli is not independent of task demands and therefore unlikely to operate automatically (Driver et al, 1999).

One possible problem with the experiments in this study is that all the stimuli were presented in foveal vision. This is a problem in the sense that it is possible that all stimuli presented in foveal vision are processed equally and therefore one would not expect to see differential congruency effects as a function of the distractor's identity. While it is certainly true that distractor congruency effects are most pronounced when the distractors are closely flanking the target (Eriksen, Pan, & Botella, 1993), it is possible to observe modulations in the congruency effect, even when targets and distractors are presented within foveal vision (Horstmann, Borgstedt, & Heumann, 2006).

The consistent finding throughout the first three experiments of this chapter is that the processing of the task-relevant central stimulus could not be done without also processing the task-irrelevant flanking stimuli. This is in line with previous work using this paradigm (e.g., Eriksen & Eriksen, 1974; Smith & MaGee, 1980). However, given that the current research shows that facial information from one source can interfere with independent facial information from another source, the results are at odds with recent work indicating that only one face can be processed at a time. Bindemann, Burton, & Jenkins (2005) asked participants to make speeded sex judgements (Experiment 1) or semantic judgements (Experiments 2 & 3) to face or non-face targets. These judgements were made while trying to ignore face or non-face distractors that could be congruent or incongruent with the target. Regardless of the task, interference effects were observed for all target-distractor pairings (word-word, word-face, and face-word) except when a face target was paired with a face distractor (face-face). Thus, their results seem to suggest there may be capacity limits in face processing such that only one face can be processed at a time.

Similarly, Lavie, Ro, & Russell (2003) employed a distractor interference paradigm to examine the processing of face and non-face distractors. Their critical manipulation was to alter the perceptual load[8] of the central task. The task was to classify a printed name as belonging to a pop star or politician (Exp.1) while trying to ignore a photograph of a face which could either belong to the same (congruent) or different (incongruent) semantic category. In traditional perceptual load experiments (e.g., Lavie, 1995), interference effects would be expected in the low perceptual load condition since there would be spare capacity to process the

[8] In Lavie's (1995) Load Theory of attention, all visual items in a display are processed until capacity is reached. In a situation with low perceptual load (e.g., only one relevant stimulus is presented) spare capacity 'spills over' to other items in the display leading to the processing of irrelevant distractors. However, in a situation with high perceptual load (e.g., many relevant stimuli are presented), maximum available capacity is reached leading to the distractors receiving no processing.

distractors. However, in the high perceptual load condition, there should be no spare capacity and therefore no distractor processing hence no interference effects. Contrary to this, Lavie et al's (2003) results revealed that the presence of the face interfered with the processing of the target stimuli at all levels of perceptual load, indicating that face processing proceeds in a mandatory fashion, independent of capacity limits which exist for other kinds of stimuli (see also Jenkins, Lavie, & Driver, 2003).

Despite this evidence, there is reason to suspect that the case for capacity limits in face processing may be limited to specific tasks. Näsänen and Ojanpää (2004) measured the number of faces that could be processed in a single fixation. Based on the number of fixations made during a visual search task to find a familiar face amongst a crowd of unfamiliar distractors, they estimated between two and four faces could be processed simultaneously. Interestingly, the time they suggest it takes to process this number of faces is 200ms, precisely the length of time Bindemann et al present their stimuli for and find only one face is processed at a time.

Furthermore, studies examining the allocation of attention between a pair of faces in the dot-probe task are based on the assumption that some processing of both of the faces is proceeding in parallel. Indeed, results show that attention is allocated on the basis of the emotional facial expression of the face when they are shown for only 100ms (Cooper & Langton, in press; Chapter 4, this thesis) and even when they are shown subliminally (Mogg & Bradley, 1999). This strongly suggests that, at the very least, information about emotional facial expression can be extracted from two faces simultaneously.

Together, this evidence challenges any strict notion that only one face can be processed at a time. However, it is possible that differences in task demands, and their accompanying attentional load, are responsible for the observed differences in effects across different experiments (Lavie, 1995). In all of the distractor interference studies showing only one face can be processed at a time (Bindemann et al, 2005; Lavie et al, 2003; Jenkins et al, 2003), participants are instructed to ignore the flanking stimuli while they focus on the central stimulus. In a sense, the participants in these experiments have two tasks: 1) discrimination of the target stimulus, and 2) inhibition of the flanking stimuli. This would arguably reflect a relatively high attentional load, and thus, only one face is processed at a time. In contrast, the visual search experiments (Näsänen and Ojanpää, 2004) require participants to search through arrays of faces as quickly as possible. Thus, they are motivated to find the target face, and therefore, the rapid processing of many faces is encouraged. In addition, they do not have the added load of actively trying to inhibit the processing of non-target stimuli. Therefore, this task arguably represents a relatively low attentional load and thus more than one face can be processed simultaneously.

Similarly, in order to reconcile the findings from the three experiments in the current chapter that show parallel processing of facial features with other work suggesting faces are processed in a serial fashion (Bindemann et al, 2005; Lavie et al, 2003; Jenkins et al, 2003), it is possible to argue that the gaze task used in Experiments 1-3 of the current chapter do not have such high task demands (attentional load) as those used in other research. The gaze task used in the current experiments may be associated with a lower attentional load than either of the tasks in Bindemann et al’s study (a sex decision and a semantic decision). The interference effects found in Experiments 1-3 could therefore be a function of relatively low task demands of the gaze discrimination task. It is also possible that only certain kinds of facial information (such as gaze) are accessible in a parallel manner whilst other kinds of facial information (such as sex) have to be accessed in a serial manner. If either or both of these possibilities are correct, then judging the sex of a central face should prevent the intrusion of distracting information. The following experiment directly tested this idea by using the same procedure as Experiment 2 of this chapter while asking participants to judge the sex of the face[9] rather than judge if the eyes are open or closed.

Experiment 4

Method

Participants – Eighteen undergraduate students (12 female, with a mean age of 19.5 years) from the University of Stirling took part for course credit. None had taken part in the previous three experiments.

Materials and Apparatus – Additional photographic images were taken of eight individuals' faces (four female). The images were edited so only the eye regions remained. The dimensions of the images were identical to those in Experiment 1.

Design and Procedure – This was identical to Experiment 1 except participants had to decide if the central face was male or female.

Results

Boxplots identified 3 participants as outliers and their data was excluded from the analysis. Another participant made more errors than 2.5 standard deviations from

[9] Previous research has shown that sex can be accurately determined from the type of facial parts displayed in Experiment 4 (Yamaguchi, Hiruwaka, & Kanazawa, 1995)

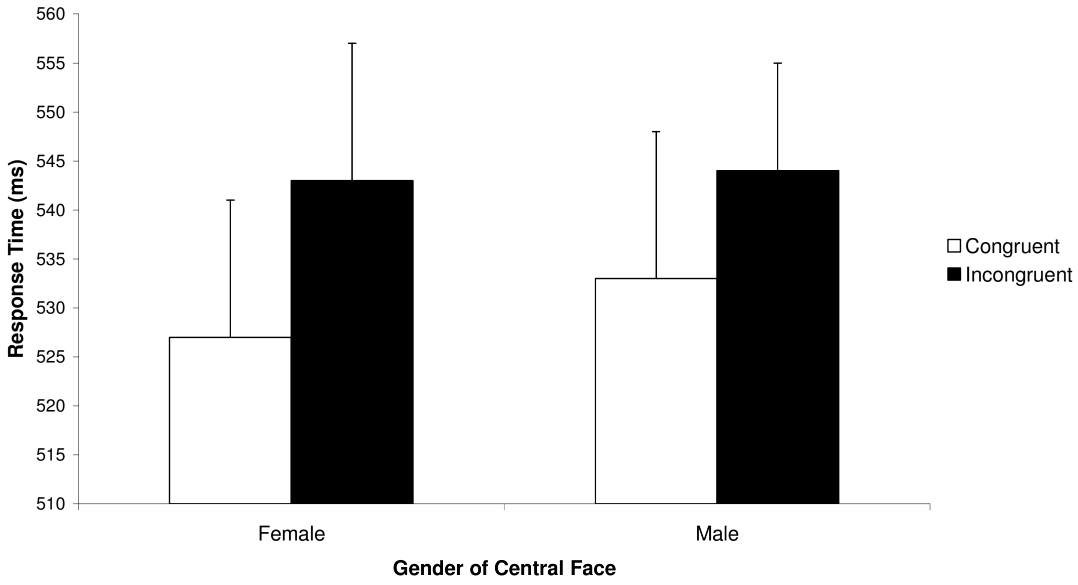

Figure 2.6: Response time (ms) to decide if centrally placed eyes are male or female while flanking eyes are congruent or incongruent using a 200ms presentation time.

the mean and was also excluded from the analysis. The interparticipant means of the remaining 14 participant's median correct responses are displayed in Figure 2.6. Inspection of Figure 2.6 indicates that responses made during congruent trials were faster than responses made during incongruent trials. These data were analysed using a 2 (central face male or female) x 2 (distractors congruent or incongruent) repeated measures ANOVA. Consistent with the data in Figure 2.6, responses made during congruent trials were significantly faster than those made during incongruent trials, $F(1,13) = 5.04$, $p = .043$. The main effect of gender and the interaction between gender and congruency were not significant ($p>.6$). Errors occurred on 9% of trials and were marginally more likely during incongruent trials (9.5%) than congruent trials (8.5%). No further analysis of errors was conducted.

Discussion

Experiment 4 departed from the method of the three previous experiments by requiring participants to decide if a pair of eyes was male or female, rather than deciding if the eyes were open or closed. This allowed more direct comparison with Bindemann et al's (2005) study which found that when making a sex judgement on a centrally presented face, a flanking face did not interfere. It was assumed that making a sex judgement to a pair of eyes would be more difficult than deciding if the eyes were open or closed. This assumption was supported by the fact that the grand mean for response times in Experiment 4 was 539ms compared with 479ms in Experiments 1-3, suggesting the former had a harder task. Furthermore, errors were more than twice as likely in Experiment 4 compared with the previous three experiments. Despite the increase in task demands, and despite Bindemann et al's findings, Experiment 4 found reliable interference effects from flanking eye pairs, a result that is consistent with the data from Experiments 1-3 of the current chapter. These results support other work (e.g., Näsänen and Ojanpää, 2004) that challenge any strict notion that only one face can be processed at a time.

General Discussion

The experiments in the current chapter were initially designed to investigate whether direct gaze is particularly difficult to ignore. Experiments 1-3 tested this idea by presenting participants with a pair of eyes and asking them to decide if the eyes were open or closed. Meanwhile, these task-relevant eyes were flanked with task-irrelevant distractor eyes that could be either congruent or incongruent with the gaze state of the central eye pair. Across the three experiments, the results consistently showed that the flanking distractors could not be successfully ignored. However, there was no evidence to support the hypothesis that eyes with direct gaze would be particularly difficult to ignore.

Despite the fact that the results from Experiments 1-3 do not support the stated hypothesis concerning the processing of gaze, they do speak to another issue relating to face processing and attention. A number of recent studies have suggested that face processing is subject to specific capacity limits such that only one face can be processed at a time (Bindemann et al, 2005; Lavie et al, 2003; Jenkins et al, 2003). In contrast, the results from Experiment 1-3, as well as results from other studies (Näsänen and Ojanpää, 2004; Cooper & Langton, in press; Chapter 4, this thesis; Mogg & Bradley, 1999) suggest that faces, or at least, certain kinds of facial information, are not subject to such limits. Accordingly, Experiment 4 replicated much of the design from Experiments 1-3 except it required participants to make sex judgements to sets of eyes, thus equating task demands with Bindemann et al (2005, Experiment 1). Despite this change in design, Experiment 4 still found reliable interference effects from flanking distractors. At the very least this suggests a revision of Bindemann et al's conclusion that faces are subject to specific capacity limits such that only one face can be processed at a time. It may be that capacity limits in face processing do exist under certain circumstances, but what is clear from the current experiments, as well as other previous research, is that these limits do not apply under all circumstances.

Bindemann et al's failure to find distractor congruency effects when a distractor face flanked a target face was, as they themselves admit, counterintuitive. What is not clear is precisely why interference effects were found in the current experiments and not in those conducted by Bindemann et al (2005). One potential explanation is that the current experiments presented only the eye region of the faces, whereas Bindemann et al presented full faces. As such, the reduction in the amount of task-relevant information on the screen would have reduced the perceptual load, thus making it more likely to obtain distractor processing (Lavie, 1995). Added to this, presentation of the eyes alone does not activate the fusiform face area[10] (FFA) to the same extent as a picture of a face (Tong, Nakayama, Moscovitch, Weinrib, & Kanwisher, 2000). Furthermore, gaze-processing tasks are thought to activate specific neural structures that similar tasks with faces do not. For example, lesions in the superior temporal sulcus (STS) in monkeys selectively impair perception of another's gaze direction without impairing face processing ability more generally (Heywood & Cowey, 1992). Thus, if the eye region alone is not processed in the same way as a full face, it may not be subject to the same attentional capacity limits as full faces, and hence distractor processing proceeds until the spare capacity is reached.

Another change in the procedure in the current series of experiments compared with Bindemann et al (2005) could help to account for the different results. In the current study a distance of only 0.9˚ of visual angle separated the mid-point of the target and distractors; whereas those in Bindemann et al study the equivalent distance was approximately 2.1˚. This is not a trivial point for two reasons: firstly, the more distant a flanker is from the target, the less likely it is to produce interference (Lavie, 1995). Secondly, since all stimuli in the current study were within 1˚ of visual angle, they would be viewed by the fovea and hence could be seen in great detail without a shift in attention (Coren, Ward, & Enns, 1998).

In the light of the results from the current chapter, a future experiment could replicate the experiments from Bindemann et al using full faces, except arrange them in the manner used in the current study. If Bindemann et al's theory of capacity limits in face processing is correct, this change in arrangement should

[10] The FFA is a region of the brain thought to be specialised in the processing of faces (Farah et al, 1998).

make no difference to the basic finding: no interference effects from the distractors would be expected. However, it may be that the capacity limit in face processing only applies to the processing of other faces out-with foveation, although this would not be consistent with results from Näsänen and Ojanpää (2004) who found between two and four faces could be processed in a single fixation lasting 200ms. This question requires further investigation for a suitable resolution.

Other future work could investigate the nature of capacity limits in face processing by using the procedure laid out by Bindemann et al (2005) to see if information concerning emotional expression can be processed from more than one face at a time. Previous work from the dot-probe task already suggests that emotional information from more than one face is processed in parallel (Cooper & Langton, in press; Chapter 4, this thesis). Differences in task demands between the flanker interference paradigm and the dot-probe paradigm could account for why parallel processing of faces was seen in one study (Cooper & Langton) and not in the other (Bindemann et al). However, there is reason to suspect that if capacity limits in face processing do exist for certain kinds of facial information (e.g., semantic information), they might not exist for information concerning emotional expression, even if subjected to higher task demands in Bindemann et al's study. This holds especially for expressions related to threat which are thought to attract processing resources to their location (Ohman et al, 2001; See also, Chapter 4, this thesis). To look for flanker interference effects with emotional expressions using Bindemann et al's procedure would, regardless of the specific outcome, give useful evidence to help understand the nature of capacity limits in face processing.

In summary, the main purpose of the current chapter was to investigate the relationship between direct gaze and attention. More specifically, it used a distractor interference paradigm to explore whether or not direct gaze is particularly difficult to ignore. Experiments 1-3 provided no evidence that direct gaze was particularly difficult to ignore. However, these experiments did show that information from more than one face can be processed simultaneously, a result that was confirmed in a fourth experiment. Taken together, these experiments add weight to other data that challenge the notion that faces are subject to specific capacity limits such that only one face can be processed at a time.

Chapter 3

Effects of task-irrelevant averted gaze on attention

Chapter 2 was primarily concerned with studying the relationship between direct gaze and attention. More specifically it investigated whether direct gaze is particularly difficult to ignore. The current chapter departs from this question and looks instead at the relationship between averted gaze and attention. It focuses on the effect that observing another's eye gaze has on shifting attention away from the face and investigates the sense in which this effect can be said to be automatic.

In general, humans and other animals direct their gaze towards events that are of interest to them. Hence, if you, as a viewer, are able to determine accurately where another person is looking, this can be a reliable way of gaining useful information about the environment (e.g., the presence of food or danger). Corresponding to this, it has been proposed that the morphology of the human eye (specifically the high contrast between the sclera and the iris) evolved to facilitate viewers' rapid and accurate detection of other people's eye direction (Kobayashi & Kohshima, 1997).

The ability to distinguish where another person is looking begins relatively early. Infants as young as three-months-old are not only able to distinguish between direct and averted gaze, but will also shift their attention in the direction corresponding with seen averted gaze (Hood, Willen, & Driver, 1998). This pattern of joint attention between a child and caregiver plays a key role in the acquisition of language as children understand that a mutually attended unfamiliar object is associated with a certain word (Baldwin, 1991).

A number of studies with adults have confirmed that viewing another person's averted gaze creates corresponding shifts in the observer's attention (e.g., Friesen & Kingston, 1998; Langton & Bruce, 1999; Driver, et al, 1999). In the typical version of these experiments a face is centrally presented with gaze averted to either the left or the right of centre. After a short delay, a target (typically one of two possible letters) then appears either to the left or right of the face. The standard finding is that despite the non-predictive nature of the gaze cue (e.g., it only indicates where the target will appear on 50% of trials) responses to identify, detect, or locate the target are faster when it appears in the gazed-at location compared to when it appears in the other, non-gazed-at location. This finding holds even when the cue becomes counter-predictive (i.e., the target is more likely to appear in the location opposite the one toward which the face is gazing). This suggests that the direction of another's gaze can produce shifts of attention which are automatic in the sense that they proceed both without, and contrary to, intention (Driver et al, 1999).

However, evidence of automaticity under certain conditions, such as occurring without, and contrary to, intention, does not imply an effect will be automatic under all circumstances (Bargh, 1992). Despite instructions in the standard gaze-cueing experiments that participants should try and ignore the direction of gaze the face adopts, the face and the gaze direction itself are always, in some sense, relevant to the task being carried out. This is due to the fact that the participants' task is to monitor a number of locations for a target. Before the target appears there is a gaze shift in one of the potential target locations. This means, there is always some relationship between the cue and the target, and in these terms, the gaze cue cannot be said to be entirely irrelevant to the task. This is important because it is not possible to ascertain whether the tendency for attention to be allocated in the direction corresponding to seen gaze is automatic in the sense that it is independent of task demands. This question is fundamental to understanding the circumstances in which this gaze-cueing effect will occur. What is not known is whether simply seeing a face with averted gaze will cue the observer's attention in the corresponding direction or whether the gazing face has to be in some way relevant to the observer's goals. There is evidence that other stimuli which were thought to shift attention automatically (e.g., sudden onsets) will only do so when they are related to the viewer's task (Most, Scholl, Clifford, & Simons, 2005).

The purpose of the current experiments was to investigate this particular notion of automaticity with the gaze-cueing effect by making gaze cues entirely irrelevant to the task that participants are required to complete. Given the limitation (see above) of the standard gaze-cueing paradigm for displaying gaze cues in a task-irrelevant fashion, it was necessary to pursue this line of enquiry with a different methodology. Thus, in the current experiments, faces with one of three possible gaze directions (left, right or direct) were placed inside a rectangular frame to the left or right of items which could be other faces (Experiment 5) or objects (Experiments 6 – 9). Participants had to make a colour judgement (red or blue) to the frame. Processing of the entirely task-irrelevant stimuli inside the frame was measured in a subsequent surprise recognition memory task as a function of whether the face was looking at the other item, looking in the opposite direction, or looking straight ahead. While measuring recognition memory for items does not provide a direct measure of how attention is allocated in the colour discrimination phase of the experiment (exposure phase) it does provide a measure of the allocation of processing resources as a function of gaze, and this measure is entirely independent of task demands.

Jenkins (2001) used an identical task to examine processing of task irrelevant faces as a function of the type of stimuli they were paired with at exposure. Faces could be paired with other faces, objects, or with nothing, while participants had to perform a colour discrimination task to the frame. In the subsequent recognition memory test, recall of previously seen faces was worst when the face had been paired with another face, compared with when it had been paired with an object or nothing at all. Apart from demonstrating that incidental memory for faces is diluted more when paired with another face compared with an object, Jenkins showed that participants do process the information within the frame despite the information being entirely irrelevant to the task. Hence, the paradigm is sufficiently sensitive to reveal differential effects on memory as a function of the types of stimuli that appear inside the frame.

There is also a large amount of evidence showing that attended items are associated with better recognition than unattended items. This is true for geometric shapes (Rock, Schauer, & Halper, 1976), line drawings (Goldstein & Fink, 1981), words (Gardiner & Parkin, 1990), as well as faces (Kellogg, Cocklin, & Bourne, 1982; Reinitz, Morrissey, & Demb, 1994; Jenkins, Lavie, & Driver, 2005). Thus, if the task-irrelevant gaze shifts attention to the other item in the frame, this should be associated with greater subsequent recognition memory for that item. Indeed, there is already some evidence that task-relevant gaze-shifts in a standard agze-cueing paradigm are associated with improved recognition memory for items seen in gazed-at locations (Jenkins, personal communication). Discovering the predicted findings would suggest that gaze-cueing effects are automatic in the sense that they arise independently from current task demands.

Experiment 5

Experiment 5 made use of the paradigm employed by Jenkins (2001). A pair of faces was placed inside a rectangular frame. One of the faces could be looking at the other face, looking away from it in the opposite direction, or looking straight ahead. The participants' task was to identify the colour of the frame within which the face stimuli were presented. The stimuli within the frame were entirely irrelevant to the participants' task. Immediately following the colour discrimination phase participants were given a surprise recognition memory test for the faces presented in the colour discrimination phase. If gaze-cueing effects are automatic in the sense that they arise independently of task demands, better recognition memory for items in the 'gaze-at' condition should be observed compared to items in the 'gaze-away' condition. Faces with direct gaze were included as a baseline measure to help clarify the nature of any effects which may arise. For example an observed difference between recall of items in the gaze-at and gaze-away conditions could be due to enhanced processing of items in the gaze-at condition, impoverished processing of items in the gaze-away condition, or a combination of both. Thus the direct gaze baseline allows an understanding of how many items can be recalled under identical exposure conditions but when gaze is not averted.

Method

Participants – Thirty undergraduate students from the University of Stirling (23 females, with a mean age of 20.5 years) took part for course credit.

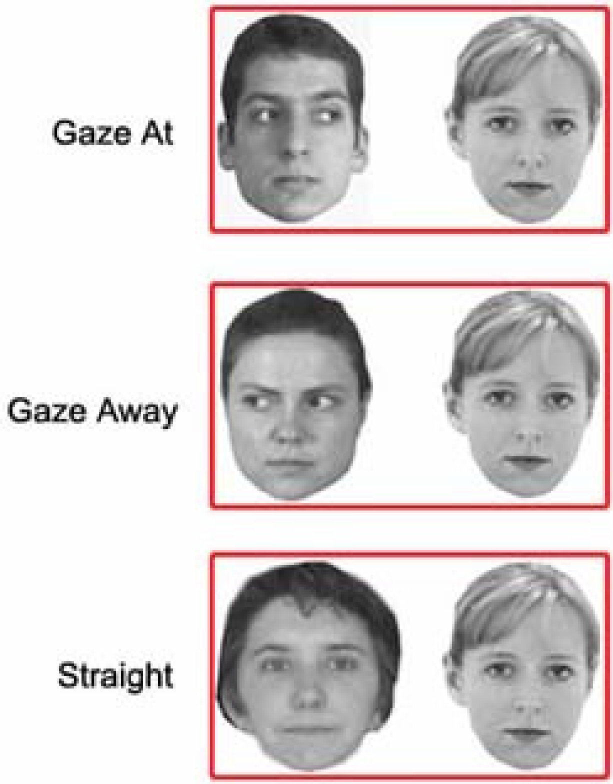

Figure 3.1: Example displays from the three experimental conditions of the colour discrimination phase of Experiment 5. Irrelevant unfamiliar faces could be presented with another irrelevant unfamiliar face gazing at it (Gaze At condition), gazing away from it (Gaze Away condition), or with direct gaze (Straight condition).

Each face in Set A was presented either to the left or right of fixation inside a rectangular frame. The frame measured 6.0 cm horizontally and 3.4 cm vertically (corresponding to 5.7° and 3.3° of visual angle). Each face from Set A was paired with a face from Set B to yield twelve face pairs in each of the three experimental conditions (see Figure 3.1). The face from Set B could be either looking at the other face, looking away from it, or also have direct gaze. Each of these face pairs was placed inside both a red and a blue frame resulting in 72 possible displays per participant. The remaining 24 faces (Face Set C) appeared as new items in the recognition memory phase (phase two) of the experiment. The presentation of

Face Sets A and C was rotated about conditions so that across participants, each face appeared in each experimental condition as well as appearing as a new item in phase two of the experiment an equal number of times. The experiment was run using SuperLab software and presented on a Macintosh I-Mac. Responses were collected on a standard Macintosh Keyboard.

Design and Procedure – Each trial began with a blank screen for 1000ms followed by a fixation cross presented for 500ms. This was followed by the presentation of the coloured frame containing the faces for 500ms. The participants' task was to respond to the colour of the frame (either red or blue) after the stimuli had disappeared from the screen by pressing one of two keys coloured red or blue (corresponding to "3" for red and "." for blue on the numeric keypad of a standard keyboard). They were told that they would see faces inside the frame but that these were not relevant to the task and, as such, could be ignored. No mention was made of the recognition test to follow. After a short practice of six trials in which only the frames were presented each participant was exposed to six blocks of experimental trials, each containing the 36 faces in Set A inside either a red or blue frame. Each face was therefore presented twelve times during the colour discrimination task. A surprise recognition memory test followed immediately after the completion of the colour discrimination task. All 36 faces from Set A were presented serially, intermixed with the 24 faces from Set C with a new random order for each participant. Participants had to decide whether or not each face had been observed in the colour discrimination phase of the experiment (constituting an old/new decision) by pressing M for "Yes" and Z for "No".

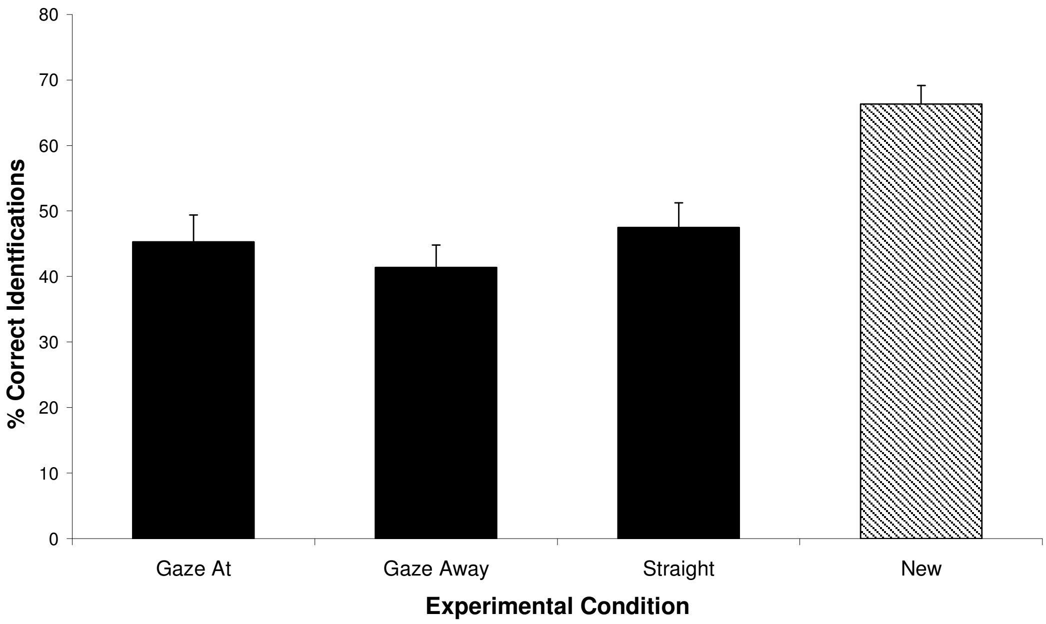

Figure 3.2: Mean percentage of correct identifications (hits for old items and correct rejections for new items, +1SE) in the surprise recognition phase of Experiment 5 as a function of experimental condition.

Results

The percentage of times participants correctly identified whether or not they had seen each test item in phase one of the experiment was calculated and the interparticipant means of these percentages are displayed in Figure 3.2. These percentages were 45.3% in the gaze at condition, 41.4% in the gaze away condition, 47.5% in the direct gaze condition, and 66.3% for new items. A repeated measures ANOVA revealed a significant effect of condition $F(3,87) = 15.6$, $p<.001$. Pair-wise comparisons revealed that the probability of correctly identifying the test faces was significantly higher for new faces than for any of the faces that had been shown in phase one of the experiment, regardless of experimental condition (all ps<.001). However, against predictions the probability of correctly identifying previously seen faces was equivalent in the three gaze conditions (all ps>.1).

Correct identification of ‘old’ items was at chance level (comparison with 50%, ps>.05) whereas identification of the new items was significantly better than chance, $t(29) = 5.63$, $p<.01$.

Discussion

The results from Experiment 5 demonstrate that the experimental manipulation in phase one had no effect on the recall of the faces. In other words, contrary to predictions, incidental memory for faces presented at test was not influenced by the direction of gaze of the face with which it was paired at exposure.

The lack of any effect of gaze on subsequent recall could be due to the fact that the gazed-at item was another face. This is a potential problem for two reasons: firstly, recent work suggests that faces may be subject to capacity limits such that only one face can be processed at a time (Bindemann, Burton, & Jenkins, 2005; See Chapter 2 for a full discussion of this idea); secondly, the other face always had gaze directed at the participant, and this is thought to attract attention to its location (von Grünau & Anston, 1995, Senju, Hasegawa, & Tojo, 2005; although see Chapter 4) as well as hold attention (Senju & Hasegawa, 2005). Thus, participants may have not even been aware of the averted gaze cue because they never attended to it; the other face inside the frame was too strong a competitor for attention. To overcome this possibility, at exposure, the following experiment paired gazing faces with objects rather than other faces, and at test, memory for the objects was tested.

Another problem with Experiment 5 is that recognition of the ‘old’ items does not differ from chance level. This is a problem because it suggests that while

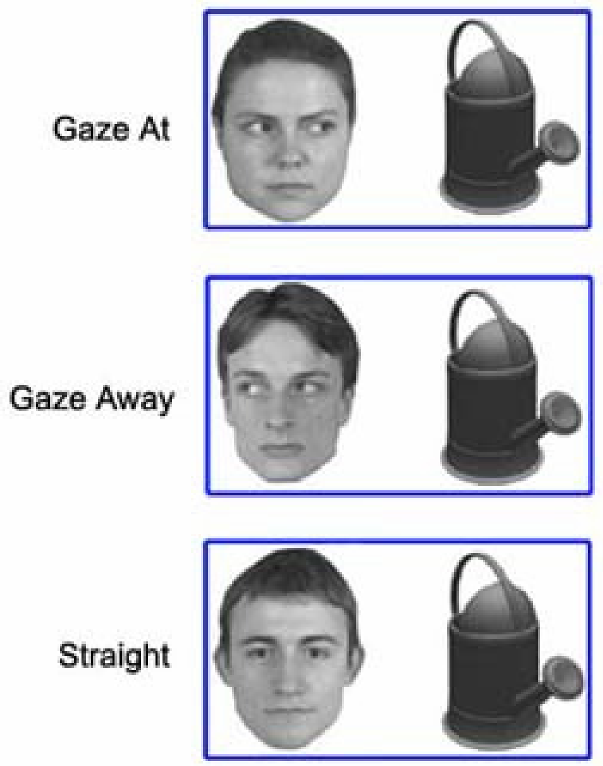

Figure 3.3: Example displays from the three experimental conditions of the colour discrimination phase of Experiment 6. Irrelevant objects could be presented with an irrelevant unfamiliar face gazing at it (Gaze At condition), gazing away from it (Gaze Away condition), or with direct gaze (Straight condition).

participants are good at rejecting the 'new' faces, they are not good at deciding if they have seen an 'old face before and may, in fact, just be guessing. Replacing faces with objects as test items should increase recognition memory (Jenkins, 2001).

Experiment 6

Participants – Fifteen undergraduate students (twelve female, with a mean age of 20 years) from the University of Stirling took part for course credit. None had taken part in Experiment 6.

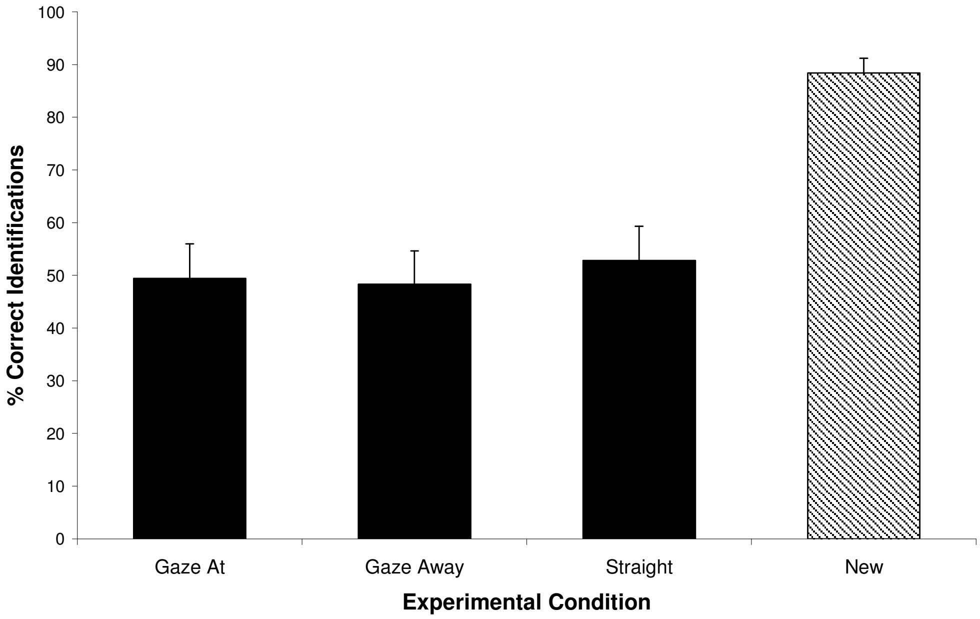

Figure 3.4: Mean percentage of correct identifications (+1SE) in the surprise recognition phase of Experiment 6 as a function of experimental condition.

Materials and Apparatus – These were identical to Experiment 5 except the stimuli in face sets A and C were replaced with equal numbers of pictures of objects (see Figure 3.3[11]). A heterogeneous set was chosen (e.g., table, lamp, iron, fridge) with no more than two objects of the same type (e.g., two chairs) being present in total.

Design and Procedure – This was identical to Experiment 5 except the coloured frames contained a face and an object rather than two faces. It was expected that the objects would be easier to remember than the faces had been in Experiment 5 due to the set being more heterogeneous than the faces. As such, the number of presentations was reduced to 6 x 500ms per face/object pair. As in Experiment 5, across participants, each object was equally likely to be seen in each of the experimental conditions in phase one and as a new item in phase two.

[11] The stimuli were selected from a computer generated set of objects. The full set can be viewed here - http://www.cog.brown.edu/~tarr/projects/databank.html.

Results

The percentage of times participants correctly identified whether or not they had seen each test item in phase one of the experiment was calculated and the interparticipant means of these percentages are displayed in Figure 3.4. These percentages were 49.4% in the gaze at condition, 48.5% in the gaze away condition, 52.8% in the direct gaze condition, and 88.3% for new items.

A repeated-measures ANOVA of these data revealed a significant effect of condition $F(3,42) = 20.54$, $p<.001$. Pair-wise comparisons revealed that the probability of correctly identifying the test items was significantly higher for new objects than for any of the objects that had been shown in phase one of the experiment, regardless of experimental condition (all $ps<.001$). However, against predictions the probability of correctly identifying previously seen objects was equivalent in the three gaze conditions (all $ps>.2$).

These data seem to suggest that participants were more able to discriminate between old and new items in Experiment 6 than they were in Experiment 5. The data from the two experiments were directly compared to ascertain whether replacing faces with objects improved item memory in phase two of the experiment. A 4 (exposure condition) x 2 (experiment) mixed ANOVA revealed a significant main effect of exposure condition ($F(3,129) = 37.661$, $p<.001$), and a significant interaction between exposure condition and experiment ($F(3,129) = 3.279$, $p = .023$). This indicates that compared with Experiment 5, the percentage of correct identifications in Experiment 6 increased for both items that had been displayed in phase one of the experiment, and for new items. This indicates that replacing faces with objects has made the recognition memory task easier. However, identification of the old items was still not better than chance (comparison with chance level, all ps>.05).

Discussion

The results from Experiment 6 demonstrate that the replacement of faces for objects as items for which memory is tested did not alter the conclusions from Experiment 5. Incidental memory for objects presented at test was not influenced by the direction of gaze of the face with which it was paired at exposure. Overall, participants had better performance in phase two of Experiment 6 than they did in Experiment 5 with correct identification of old and new items increasing. This is consistent with the assumption that exchanging the test items (faces) in Experiment 5 with objects in Experiment 6 would make the task easier. However, it is important to note that identification of 'old' items was still not above chance level.

One possible reason that incidental memory for objects was not affected by the condition in which it was seen in phase one of the experiment is that the anticipated gaze cueing effects may take longer to arise than was originally supposed at the outset of Experiment 5. Previous work using the gaze-cueing paradigm has found that attention is consistently cued to the gazed-at location from stimulus onset asynchronies (SOAs) as short as 100ms (Langton & Bruce, 1999). However, it is not known if the simultaneous presentation of other items in the display will disrupt this effect, perhaps meaning it takes longer to manifest itself. To guard against this possibility in the following experiment participants were exposed to each display for 800ms in phase one. The increased exposure duration should also improve recognition accuracy for previously seen items which are at chance level in both Experiments 5 and 6.

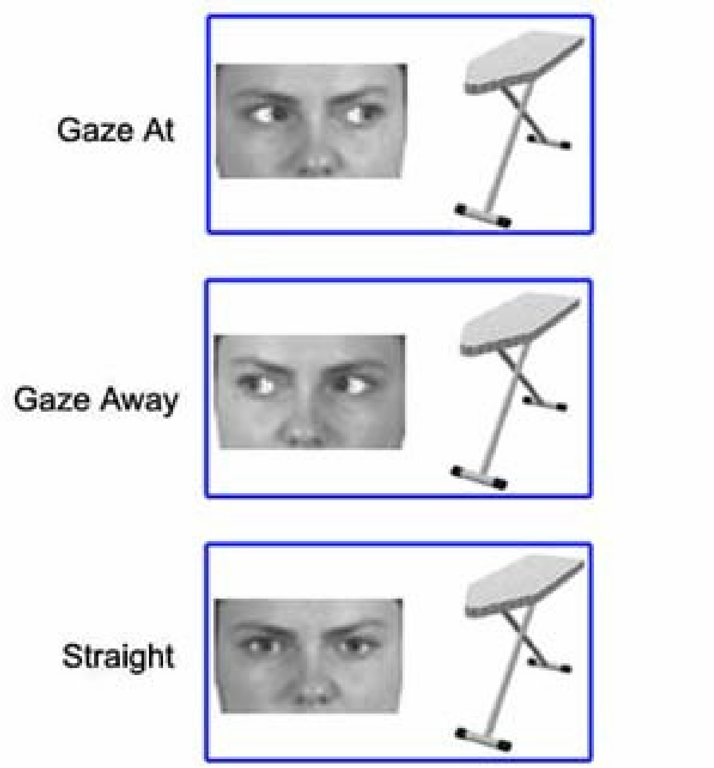

Figure 3.5: Example displays from the three experimental conditions of the colour discrimination phase of Experiment 7. Irrelevant objects could be presented with an irrelevant unfamiliar face gazing at it (Gaze At condition), gazing away from it (Gaze Away condition), or with direct gaze (Straight condition).

It is also possible that participants can easily ignore the gaze cues in the context of this experiment. Accordingly, another change was to increase the salience of the gaze cue. This was achieved by removing part of the face and making the eye region larger (see Figure 3.5).

Experiment 7

Participants – Fifteen undergraduate students (fourteen female, mean age 37 years) from the Open University volunteered to take part. They received no payment for their involvement in the study.

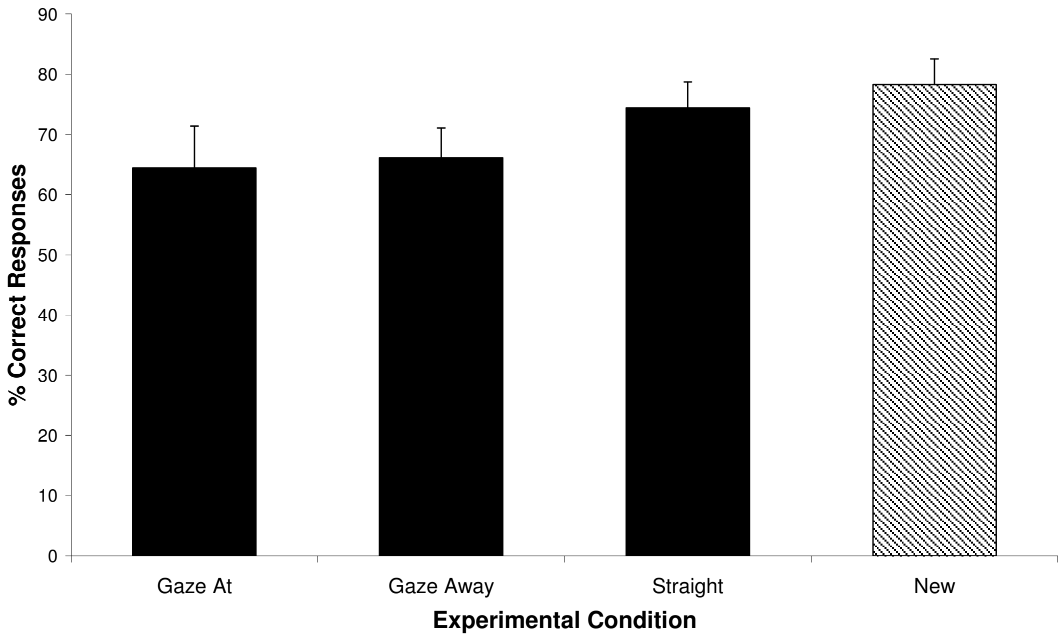

Figure 3.6: Mean percentage of correct identifications (+1SE) in the surprise recognition phase of Experiment 7 as a function of experimental condition.

Materials and Apparatus – The objects from Experiment 6 were utilised but were this time paired with one of only five faces in each of the three experimental conditions gaze at, gaze away, and direct). The salience of the gaze cue was increased by using Adobe Photoshop to remove the external features of the face as well as the mouth to leave an image containing only the eyes and nose region. This region was then enlarged to measure 2.2° x 1.2° of visual angle (see Figure 3.5). The experiment was run using SuperLab on a Macintosh G3 laptop.

Design and Procedure – This was identical to Experiment 6 except for the following changes. The stimuli in the colour discrimination phase of the experiment remained on the screen for 800ms and each object-face pair was now only shown twice. Participants were instructed to respond to the colour of the frame after the offset of the stimulus. For each participant the identity of the face in the frame during the colour discrimination phase did not change. However across the 15 participants five different faces were each seen three times.

Results

The percentage of times participants correctly identified whether or not they had seen each test item in phase one of the experiment was calculated and the interparticipant means of these percentages are displayed in Figure 3.6. These percentages were 64.4% in the gaze at condition, 66.1% in the gaze away condition, 74.4% in the direct gaze condition, and 78.3% for new items. Against predictions, a repeated measures ANOVA revealed no significant differences between any of the conditions $F(3,42) = 2.37$, $p = .08$. One-sample t-tests revealed that all responses were above chance responding (all $ps > .05$).

Discussion

The results from Experiment 7 demonstrate that increasing the salience of the gaze and the length of time the items were exposed to the participants had no impact on the conclusions from both Experiments 5 and 6. Incidental memory for objects presented at test was once again not influenced by the direction of gaze of the face it was paired with at exposure. However, the changes in procedure now improved participant accuracy in this task, taking performance above chance level, supporting the conclusion that participants can actually process the items inside the box.

Another possible explanation for the inability to display any effects of gaze direction is that in a standard gaze-cueing experiment a face is presented at fixation with gaze averted and this presentation is followed by the appearance of a target in either a valid (gazed at) or invalid location. As such, it is known that participants' attention is initially directed toward the face on each trial. In the current series of experiments the frame and both items contained therein, appear simultaneously. Given that a number of different visual stimuli appear together, and the face is irrelevant to the task, it is possible that participants never attend to it. This could account for the inability to show any differential effects as a function of gaze direction across Experiments 5-7. To this end, the following experiment directly manipulated the participants' attention. In phase one, half the participants performed a colour discrimination task to the frame, and the other half performed a colour discrimination task to the faces themselves which were now also coloured red or blue. Given that half the participants were now explicitly required to attend to the face in order to complete phase one of the experiment, this, in theory, increased the likelihood that gaze-cueing effects will be observed in phase two of the experiment. Previous research looking at face processing as a function of attentional load at exposure (see Chapter 2) has determined that a colour discrimination task is associated with low attentional load, allowing enough processing resources to ensure that the face is processed (Jenkins, Lavie, & Driver, 2005).

Experiment 8

Participants – 40 undergraduate students (30 female, with a mean age of 36) from the Open University volunteered to take part. They received no payment for their involvement in the study.

Materials and Apparatus – These were identical to Experiment 7 except the faces inside the frame were now also coloured red or blue (see figure 3.7) using Adobe Photoshop. Each object was paired with a red and a blue face and across participants was equally likely to be placed inside a red or blue frame.

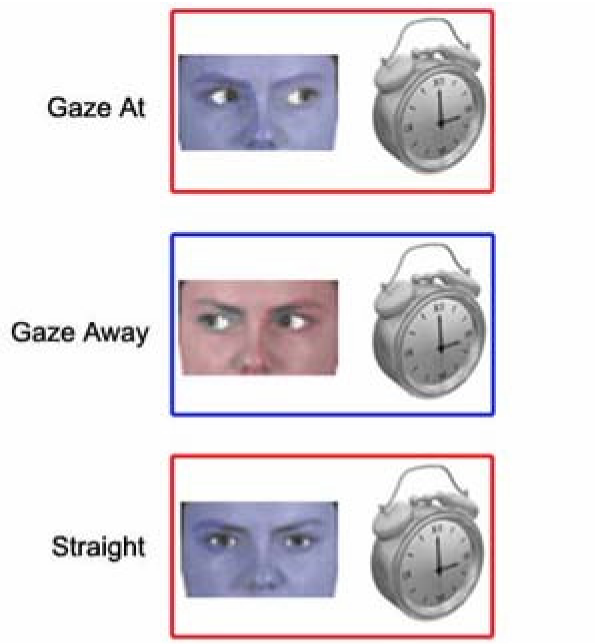

Figure 3.7: Example displays from the three experimental conditions of the colour discrimination phase of Experiment 8.

Design and Procedure – This was identical to Experiment 7 except a between subjects factor of task type was added. In phase one (colour discrimination task), half the participants had to make a colour decision to the frame while the other half had to make a colour decision to the face inside the frame.

Results

The percentage of times participants correctly identified whether or not they had seen each test item in phase one of the experiment was calculated and the interparticipant means of these percentages are displayed in Figure 3.8. A 4 (exposure condition) x 2 (task: colour discrimination of face or box) mixed ANOVA revealed a significant main effect of condition $F(3,108) = 26.09$, $p<.001$. Pair-wise comparisons revealed the probability of correctly identifying the objects that had been seen in phase one of the experiment was significantly lower than to new objects regardless of exposure condition or task (all $ps<.001$). The between-

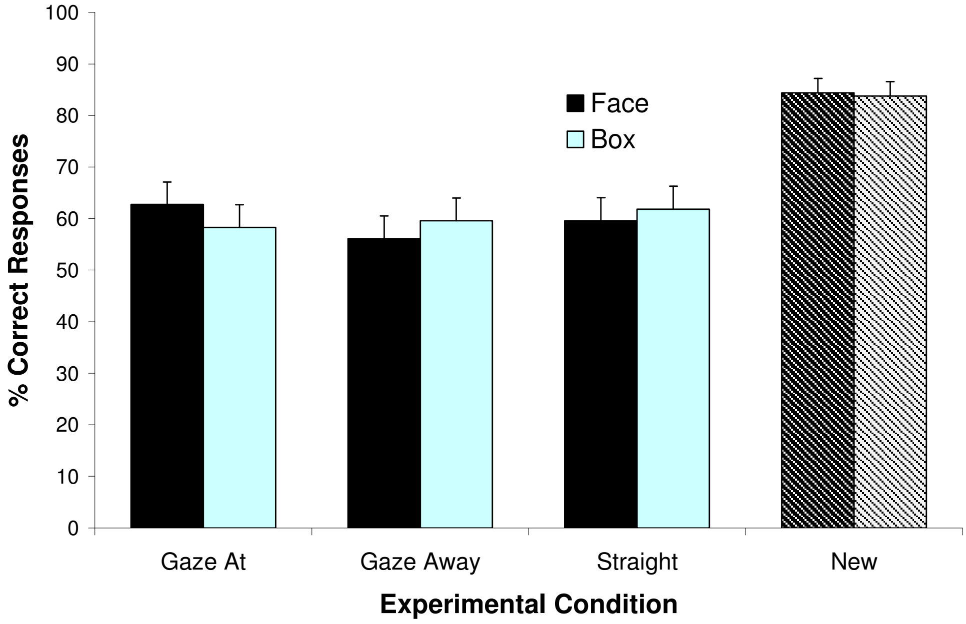

Figure 3.8: Mean percentage of correct identifications (+1SE) in the surprise recognition phase of Experiment 8 as a function of experimental condition.

subjects factor of task and the interaction between exposure condition and task did not approach significance (ps>.5). A planned between-subjects comparison of the Gaze At condition did not approach significance, t(38) = 1.01, p >.3. Consistent with the results of Experiment 7, the data in all of the experimental conditions were different from chance, at least marginally (all ps<.06), with the exception of the gaze away condition for participants in the group making the judgement about the faces (p>.1).

Discussion

The purpose of Experiment 8 was to compare the recognition memory of two groups of participants: One group whose task was concerned with the face stimuli inside the frame and another group whose task was concerned with the frame itself. The assumption underlying this manipulation was that any gaze cueing effects arising from the faces inside the frames would be enhanced for participants who were asked to attend to the face compared to those who were asked to attend to the frame in order to do their task. The results from Experiment 8 demonstrate that manipulating the task in phase one did not alter the conclusions from Experiments 5 – 7. Incidental memory for objects presented at test was once again not influenced by the direction of gaze of the face it was paired with at exposure. This was regardless of whether participants responded to the faces or the frames at exposure.

The main prediction of the preceding experiments was that items being gazed at will be preferentially processed and subsequently remembered better than items not being gazed at. The findings from Experiment 8 raise the possibility that despite evidence that attention is automatically cued by eye gaze (Langton and Bruce, 1999; Driver et al, 1999; Friesen & Kingstone, 1998), this automaticity may be contingent upon certain task characteristics. For example the results from the preceding four experiments would suggest that gaze cueing effects do not occur when the participant is engaged in a task unrelated to the face (Experiments 5 – 7) and even when the task is relevant to the face but unrelated to the spatial locations being cued (Experiment 8). However, an alternative explanation for the results from these four experiments is that the paradigm that has been employed throughout is not sensitive to the gaze-cueing effects that one would expect to observe with these stimuli. Perhaps attention is being cued effectively to the appropriate locations but this is not transferring to greater recognition memory for gazed-at items. The following experiment investigates this possibility by directly manipulating attention to the to-be-remembered items at exposure.

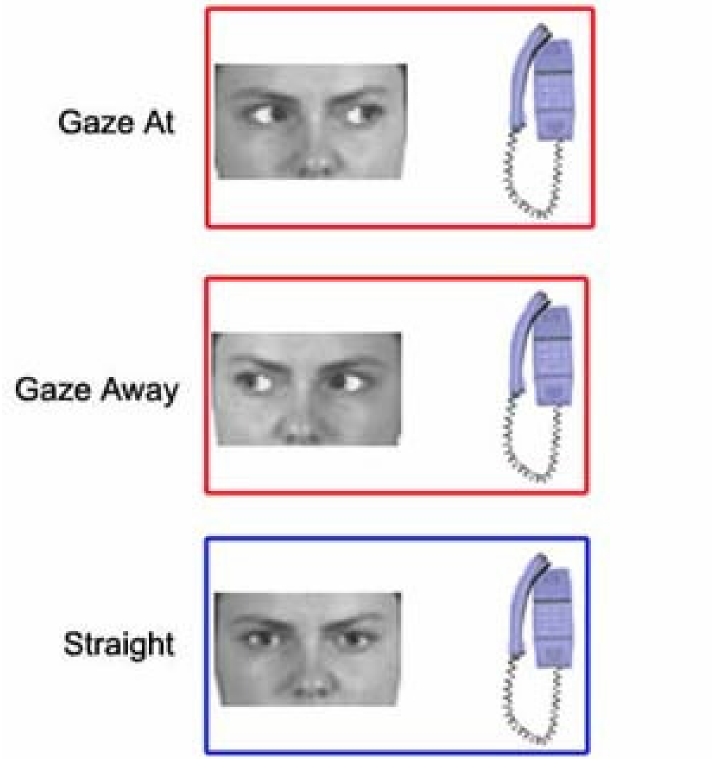

Figure 3.9: Example displays from the three experimental conditions of the colour discrimination phase of Experiment 9. Irrelevant objects could be presented with an irrelevant unfamiliar face gazing at it (Gaze At condition), gazing away from it (Gaze Away condition), or with direct gaze (Straight condition). Half of the participants responded to the frame colour, the other half responded to the object colour.

Experiment 9

In phase one of Experiment 8, half the participants performed a colour discrimination task on the frame while the other half performed the same task on the face inside the frame. Experiment 9 continued to ask half the participants to perform a colour discrimination task on the frame but asked the other half to perform the same task on the objects themselves. Therefore this second group were directly attending to the objects throughout phase one of the experiment. If the recall of items in this group is superior to the recall of items in the gaze-at condition of the group performing the colour discrimination task on the frame it would suggest the gaze-cueing attention manipulation has been unsuccessful in shifting attention throughout all preceding experiments. It would also suggest that this paradigm is sufficiently sensitive to reveal differences in recall of previously seen irrelevant items as a function of the location of attention in phase one (colour discrimination phase).

Participants – Thirty undergraduate students (22 female, with a mean age of 19 years) from the University of Stirling took part for course credit.

Materials and Apparatus – These were identical to Experiment 7 except the objects were coloured blue or red (see Figure 3.9).

Design and Procedure – This was identical to Experiment 7 except a between-subjects factor of task type was added. In phase one (colour discrimination task), half the participants had to make a colour decision to the frame while the other half had to make a colour decision to the object inside the frame.

Results

The percentage of times participants correctly identified whether or not they had seen each test item in phase one of the experiment was calculated and the interparticipant means of these percentages are displayed in Figure 3.10. Inspection of this figure indicates better memory for the objects in the group who were asked to attend to the objects compared with the group who were asked to attend to the frame. A 4 (exposure condition) x 2 (task: colour discrimination of object or box) mixed ANOVA confirmed this observation revealing a significant main effect of task, $F(1,28) = 15.84$, $p < .001$, reflecting greater recall for items by participants performing the colour discrimination task to the object compared to the

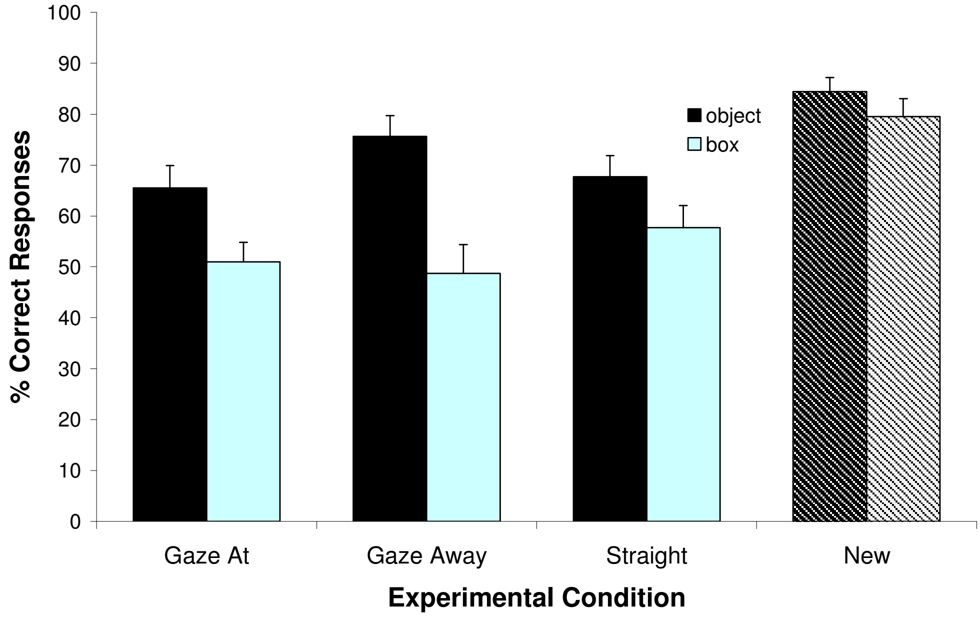

Figure 3.10: Mean percentage of correct responses (+1SE) in the surprise recognition phase of Experiment 9 as a function of experimental condition.

frame. A significant main effect of condition, $F(3,84) = 18.06$, $p<.001$, and a significant interaction between the two factors, $F(3, 84) = 3.47$, $p = .02$, were also observed. Simple main effects analysis revealed that the data from both the object task and the frame task conditions had a significant simple main effect of exposure condition ($p<.001$ for both comparisons). For both groups, pair-wise comparisons revealed the probability of making a correct response to objects that had been seen in phase one of the experiment was significantly higher than to new objects regardless of gaze condition at exposure (all ps<.001). For the object task group only, pair-wise comparisons revealed participants were correct significantly more often to items in the gaze-away condition compared with the gaze-at condition ($p = .018$). No other effects approached significance ($p>1$).

Comparisons of each of the conditions against chance performance (50%) revealed that the data in all four conditions for the 'object' group was significantly different from chance (all ps<.05). However, with the exception of the data from the new items, responses from participants in the 'box' condition were not significantly different from chance.

Discussion

The purpose of Experiment 9 was to investigate the sensitivity of the paradigm that has been used throughout this chapter. The main question was whether or not it was sensitive to manipulations of attention such that attended-to items would be remembered more often than items that were not attended to. The results from this experiment provided convincing evidence that when participants had to perform a colour discrimination task on objects in phase one (i.e., there is no doubt that participants are attending to the objects) they showed greater recall of those items in a subsequent surprise recognition memory test compared to those who were asked to perform their task on the frame inside which the items are placed. This finding is consistent with other work which has shown that attended items are associated with greater subsequent recognition memory than unattended items (e.g., Goldstein & Fink, 1981; Gardiner & Parkin, 1990). This suggests that if attention is being cued to the location of the object in 'gaze-at' trials (as was the underlying assumption throughout all the experiments in this chapter) this should result in the predicted increase in memory for these items. However, the results from the participants conducting the colour discrimination task on the frame once again demonstrated no increase in recognition memory for items that were being gazed at compared to items being gazed away from. This is consistent with the results from Experiments 5 – 8 which also found no differences between the different gaze conditions.

Surprisingly, given the lack of effects from four previous experiments, the current experiment did reveal a difference between the gaze conditions for participants performing the colour discrimination task on the objects. However this difference was in the opposite direction than would be expected given evidence from previous research showing that attention is shifted to gazed-at locations (e.g., Langton & Bruce, 1999). This suggests the counter-intuitive conclusion that observing someone gazing at an object not only fails to increase later memory for that object, but actually, under the condition where the gaze is irrelevant to the task, gaze is only helpful to later memory when it is directed away from the object. While it would be premature to make bold claims on this basis, given the amount of evidence, both empirical and anecdotal, that would predict the opposite effect, what is clear is that at the very least, a gaze cue towards the location of an object when both are irrelevant to the task, does not improve subsequent recognition memory for that object.

General Discussion

The five experiments presented in this chapter were designed to investigate the nature of the gaze-cueing effect and specifically ascertain whether its observed automaticity in terms of arising without, and contrary to, intention (Driver et al, 1999) extends to circumstances in which the gaze cue is entirely irrelevant to the current task. Throughout these experiments the primary prediction was that memory for task-irrelevant items paired with a face which gazed at the item would be better than memory for similar items that had not been gazed at. Across all five experiments there was no evidence to support this prediction.

The underlying assumption for this prediction was that viewing another's averted gaze would create a corresponding shift in the viewer's own attention. In the condition where gaze was directed towards the object it was assumed this would cause a shift in the viewer's attention towards the object and hence increase the degree to which that object was processed and subsequently remembered. This assumption was based on evidence from a number of researchers showing reliable gaze-cueing effects (Langton & Bruce, 1999; Driver et al, 1999; Friesen & Kingstone, 1998). Despite this evidence, the current experiments gave no hint that task-irrelevant gaze direction led to increased memory performance for items in gazed-at, compared to non-gazed-at locations.

This inability to observe any differential effects of gaze was despite making a number of changes to the experimental design across the five experiments which were intended to increase the likelihood of observing an effect. The items for which memory was tested in Experiment 5 were faces. After no differential effects of exposure condition were found it was suggested that presenting two faces simultaneously may have diluted any gaze-cueing effects. To test this possibility Experiment 6 presented 'gazing' faces paired with objects instead of other faces in phase one of the experiment and this time memory for the objects was tested. Despite an overall increase in performance on the memory task (higher hits, lower false alarms) no differential effects of exposure condition were found.

One possible explanation for finding no observed differences in Experiment 6 was that cueing effects might take longer to arise when they were not in any way relevant to the current task. It was also supposed that the gaze signal might not be sufficiently salient in the display to create a corresponding attentional shift. To test these possibilities, Experiment 7 both increased the exposure duration of items in phase one of the experiment as well as increasing the salience of the gazing stimuli. Once again no differential effects of exposure condition were found.

Experiment 8 went a step further and divided the participants into two groups. Half of the participants had to complete the colour discrimination task (phase one) as in Experiment 7 by responding to the colour of the frame, while the remaining half had to respond to the colour of the face which had now also been coloured red or blue. The reasoning behind this manipulation was that participants responding to the colour of the face would be required to attend to the face in order to do their task, and thus, would be more likely to display cueing effects associated with perceiving faces with averted gaze. However, once again, no differential effects of exposure condition were found.

Finally, Experiment 9 examined the sensitivity of the paradigm that had been used in Experiments 5 – 8 to ascertain whether it would reveal any memory effects based on the location of attention during phase one (colour discrimination phase). Accordingly, participants were once again divided into two groups and in phase one, one group responded to the colour of the frame and the other group responded to the colour of the object itself. Once again, no differential effects of exposure condition were found. However, this time there was a reliable increase in recall of items for participants who attended to the colour of the object in phase one compared with those who attended to the colour of the frame. This finding is consistent with previous research showing that attended items are associated with better subsequent recognition memory than unattended items (e.g., Goldstein & Fink, 1981; Gardiner & Parkin, 1990).

Taken together, the data from these five experiments suggest that gaze-cueing effects do not occur when participants are engaged in a task that is entirely irrelevant to the direction of gaze of observed faces. The implication of this is that while gaze cues may be stimuli that reliably predict the location of interesting events in the environment, they will not automatically shift our attention if we are already involved in an unrelated task. This finding is important in the sense that it helps to define the limits of the gaze-cueing effect and stresses that it does not occur under all circumstances. However, whether the suggestion that only task-relevant gaze cues produce shifts in attention will also be shown outside the laboratory (i.e., in more 'real-world' settings) is an open question.

A possible explanation for the lack of gaze-cueing effects which has not yet been considered is that one major difference between the current experiments and the standard gaze-cueing experiments is that in the standard gaze-cueing experiments the face is initially presented alone at fixation whereas in the current study the face is presented simultaneously with the to-be-remembered item, and both are inside a coloured frame. It is possible that gaze-cueing effects are observed only when the face appears at fixation and is not surrounded by other items. However, this possibility is easily dismissed with consideration of the circumstances in which gaze cues are used in the 'real world'[12]. It is certainly not the case that faces are only seen surrounded by blank space. Gaze cueing in the natural environment would, by its very nature, mean that it would occur within a context where the face is one of many possible stimuli that can be processed. Langton, O'Donnell, Riby, & Ballantyne (In press) have employed the change blindness paradigm to show effects very reminiscent of standard gaze-cueing effects but with natural scenes. Participants viewed two pictures of the same scene which were presented one after the other in quick succession with a blank slide in between. The standard finding with this type of study is that participants find it difficult to notice changes between

[12] To date, no study has shown that the gaze cueing effects seen in the laboratory can also be observed in the 'real world'. It is possible that there are qualitative differences between the two.

the two pictures. However, in Langton et al's study some scenes contained a person who could be directing their attention either towards or away from the location of the change. They found that participants noticed the image change reliably faster when the person was looking towards the location of the change compared to when they were not. This provides good evidence that observing averted gaze in a natural image produces similar kinds of effects as have been found with faces presented on their own at fixation[13]. As such, the notion that the faces in the current study could not produce cueing effects because they were presented simultaneously with other images seems an unlikely account for the results presented here.

Another possible explanation for the inability to observe differential effects of gaze direction is presentation duration. In standard gaze-cueing experiments, shifts in attention to the location corresponding to the observed direction of gaze are recorded at stimulus onset asynchronies (SOAs) as short as 100ms (Langton & Bruce, 1999), and have been shown to extend to SOAs of at least 700ms (Driver at al, 1999). Experiments 5 and 6 in the current chapter presented stimuli for 500ms and Experiments 7 – 9 presented them for 800ms. It was assumed that this would be sufficient time to allow any gaze-cueing effects to arise. However, given that participants are engaged in a colour discrimination task at the same time they are exposed to the other items, it is possible that the expected gaze-cueing effects might have been observed if the stimuli had been shown for a longer duration, thus giving more time for the effects to arise. While this possibility cannot be discounted, it is unlikely to be responsible for the current data. Previous research

[13] Although, in experiments where faces are presented alone at fixation, there is often a dynamic component to the shift in gaze direction such that the eyes appear to move (e.g., Driver et al, 1999). This may be an important contributory factor to results in this paradigm.

has found a similar colour discrimination task to be associated with low attentional load and was not sufficiently demanding to halt the processing of a simultaneously presented face (Jenkins et al, 2005). Thus, there would have been ample time for the items within the frame to be processed. Indeed, one clear finding from the five experiments is that participants were able to discriminate between old and new items suggesting that the items within the frame were processed. However, despite this, the gaze cues had no effect on subsequent recognition memory for the items.

This leads to the conclusion that the reason that another's gaze did not lead to greater memory for items in gazed-at locations in this study was because the gaze-cueing effect is not automatic in the sense that it is independent of task demands. In other words, no shift in attention was observed throughout these five experiments because the participants' goal of completing the task (i.e., make a colour judgement) overrode the attention-shifting power of the gaze stimuli[14]. This is consistent with results in other areas of the attention literature where the evidence strongly suggests that many effects (if not all) which are related to the orienting of spatial attention are contingent, at least to some extent, on top-down factors such as attentional set (what the viewer expects to perceive) and task demands (Most, Scholl, Clifford, & Simons, 2005). For example, stimuli that are reliably shown to capture attention under a variety of circumstances (e.g., motion, sudden onsets) will not capture attention when the participants have adopted a specific attentional set which does not incorporate the appearance of these items into their task expectations (Yantis & Jonides, 1990).

[14] In these experiments it is impossible to completely rule out the possibility that the gaze stimuli did result in a shift in attention, but one that was not strong enough to influence the subsequent memory for the seen items.

In conclusion, based on the findings of five experiments using a recognition memory paradigm, the data from the current chapter suggest that attentional shifts that are thought to occur in response to viewing another's averted gaze do not occur automatically in the sense that they are independent of task demands. This is in line with work in other areas of attention which indicate the observation of stimulus-driven effects can often be contingent upon that stimuli's relevance to the current task.

Chapter 4

Effects of Eye Gaze and Emotional Expression on the Allocation of Attention to Faces

The previous two chapters examined the relationship between eye gaze and attention. Chapter 2 looked at whether direct gaze is particularly difficult to ignore and Chapter 3 looked at whether averted gaze will shift the viewer's attention even when the gaze cues are entirely irrelevant to the task. The current chapter examines the allocation of attention to faces as a function of their emotional expression and investigates whether this is modulated by gaze direction.

Investigations into the relationship between attention and emotional facial expression are typically put in an evolutionary context with the hypothesis being that stimuli which represent danger (e.g., angry faces) should automatically attract attention to their location due to the threat they pose to the viewer (Le Doux, 1996; Öhman, 2002). Work to support this claim has found evidence that threat-related information is processed preattentively (Morris, Öhman, & Dolan, 1998) and that attention is allocated to its location (Öhman, Flykt, & Esteves 2001a; although see Tipples, Young, Quinlan, Broks, Ellis, 2002, for an alternative view). Accordingly, a number of studies using a variety of different methodologies have shown that attention appears to be captured by angry facial expressions relative to other emotional expressions (e.g., Öhman, Lundqvist, & Esteves, 2001b; Fox et al, 2000; Eastwood et al, 2001; White, 1995; although see Hunt, Cooper, Hungr, & Kingstone, in press). For example, Öhman et al (2001b) presented participants with a visual search task in which they had to decide if all the faces in a display were the same or if there was one different. They found that when the 'different' face was angry it was detected more quickly than when it was happy. However, in common with every other study looking at this issue, the faces in Öhman et al's study had gaze directed at the viewer. This means it is not possible to say whether the presence of anger in the display is enough to capture attention or whether the anger has to be directed at the viewer (i.e., direct gaze) for attention to be captured.

The fact that no study to date has examined the role of gaze in the allocation of attention to emotional facial expressions is surprising given what is already known about the relationship between eye gaze and attention. As already discussed, there is evidence that perceiving another's eyes has a number of different effects on the subsequent allocation of attention depending on where their gaze is directed. Firstly, evidence from the visual search task suggests that attention may be drawn to the location of direct gaze faster than it is to the location of averted gaze (von Grünau & Anston, 1995; Senju, Hasegawa, & Tojo, 2005). Secondly, once mutual eye-contact is made, it is particularly difficult to disengage attention from that location if the mutual gaze is maintained (Senju & Hasegawa, 2005). Thirdly, if while looking at another's eyes, their gaze shifts to a different location in the environment, this can create a corresponding shift in the viewer's attention towards the location of interest (Friesen & Kingstone, 1998; Driver et al, 1999; Langton & Bruce, 1999). The data from these three strands of research highlight the important role that gaze has in the allocation of attention to faces, even when no emotion is being expressed.

While it is possible that attentional effects relating to eye gaze operate independently from those relating to emotional facial expressions, work on the perception of these facial attributes suggests that their processing interacts. Ganel, Goshen-Gottstein, and Goodale (2005) directly examined the question of whether the processing of emotion and gaze proceeds independently or whether they necessarily co-occur. They used the Garner interference paradigm (Garner, 1974), a methodology specifically designed to assess whether different dimensions of a stimulus can be processed independently from one another (see Chapter 1 for a description of this paradigm). Ganel et al found that participants could not make judgements about the emotional expression on the faces without being influenced by the associated gaze direction. Based on this finding it is possible to conclude that the perception of emotional facial expressions is not independent of gaze direction. However, they also found that participants could make judgements about gaze direction without being influenced by emotional facial expressions. Therefore, it is also possible to conclude that the perception of gaze direction can be independent of emotional expression.

The conclusion that the perception of emotional expression is modulated by gaze direction gains support from two studies by Adams and colleagues who found participants' ability to name emotional expressions (Adams & Kleck, 2005), and the neural activation associated with viewing the faces (Adams, Gordon, Baird, Ambady, & Kleck, 2003), was modulated by gaze direction. Furthermore, in the perception study (Adams & Kleck, 2005) there was an interaction between emotional expression and gaze direction such that certain expressions (e.g., angry and happy) were more readily identified with direct gaze, whereas other expressions (e.g., fear and sadness) were more readily identified with averted gaze. Adams and Kleck's (2005) approach/avoidance hypothesis contends that since certain expressions (e.g., anger and happiness) are associated with scenarios where the likely behaviour of the person signalling the expression would be to approach the other individual, this would explain why they are more readily identified with direct gaze. Whereas, other expressions (e.g., fear and sadness) are associated with scenarios where the person is likely to avoid interaction and hence these expressions are more readily identified with averted gaze.

While these studies provide clear evidence that gaze direction does affect the perception of emotional expressions, there is no evidence addressing the question of whether the effects seen with perception will translate to tasks that measure attention. This issue is important because it probes the extent to which selective attention discriminates between certain kinds of socially meaningful visual information. In other words, it helps identify which aspects of a facial signal influence the allocation of visual attention. Given that there is evidence suggesting that attention is preferentially allocated to the location of angry facial expressions (e.g., Öhman et al, 2001), and given also that the perception of various facial expressions is modulated by gaze direction (Adams & Kleck, 2005), the experiments in the current chapter investigated whether the allocation of attention to emotional facial expressions is modulated by the associated gaze direction.

Previous attempts to study the link between emotional facial expression, gaze direction, and attention focussed on examining whether the allocation of attention in response to gaze direction is modulated by the associated emotional expression. Three studies (Yoshikawa & Sato, 2001; Mathews et al, 2003; Hietanen & Leppänen, 2003) all reasoned that since different emotional expressions communicate different signals, certain signals should produce larger cueing effects when associated with averted gaze compared with other signals (e.g., fear or surprise). Using a standard cueing paradigm they manipulated the expression adopted by a centrally presented face. All studies found faster responses to targets presented in the cued location. However, only the Yoshikawa and Sato study found a universal tendency for this effect to be modulated by the emotional expression of the central face, with surprised faces producing a greater cueing effect than the others. Mathews et al also found some modulation by emotional expression (for fearful faces) but only in individuals measuring high in trait anxiety[15]. Hietanen and Leppänen's study found no evidence that expression modulated the basic cueing effect.

These studies suggest that the allocation of attention in response to another's gaze direction may be modulated by emotional expression, but only under certain circumstances. This is broadly in line with the results of Ganel et al (2005) which revealed that the perception of gaze direction is not modulated by the associated emotional expression. This suggests that for both attention and perception, the processing of gaze direction is largely independent of the processing of emotional expression. What is not fully understood is the converse of this relationship, that is, whether the processing of emotional expression is modulated by gaze direction. Given the evidence that the perception of emotional facial expressions is modulated by gaze direction (Adams et al, 2005; Adams & Kleck, 2005; Ganel et al, 2005, Wicker et al, 2003) it is of interest to examine whether this modulation holds for the interaction with attention.

Measuring the allocation of attention to faces as they vary in both emotional expression and gaze direction will extend the previous work showing how attention is allocated to emotional expressions. As already mentioned, all the work to date looking at how attention is allocated to emotional facial expressions has presented faces with direct gaze. In other words, the emotional signal is always directed at

[15] High levels of anxiety are typically associated with greater sensitivity to threat-related stimuli (Mogg & Bradley, 1998; Chapter 5, this thesis).

the viewer. This makes it impossible, in these experiments, to determine whether attention is being allocated to the face because it is expressing an emotion per se, or whether it is being allocated to the face because the emotional signal is being sent directly to the viewer. Le Doux's (1996) notion that processing resources are initially allocated to threat-related stimuli on the basis of a 'quick-and-dirty' analysis of stimulus features would suppose that gaze direction should not make a difference to the initial allocation of attention since angry faces with direct and averted gaze are still both potentially dangerous. However, this depends on whether or not gaze direction, in particular, is analysed preattentively, as seems to be the case for faces more generally (Hershler & Hochstein, 2005). If it is, this would predict that gaze direction should modulate the allocation of attention to emotional expressions.

The experiments in this chapter make use of the dot-probe task. In its most commonly used form the dot-probe task involves the presentation of a pair of stimuli for a fixed period of time (usually 500ms) followed by the appearance of a visual probe in one of the two stimulus locations. Participants then have to perform a task involving the probe (i.e., identification or localisation), and the distribution of spatial attention between the initially presented stimulus pair is inferred by comparing the speed of manual responses to the probe at each of the stimulus locations (following Posner, Snyder, & Davidson, 1980; Navon & Margalit, 1983). For the purposes of the current chapter, this paradigm has two main advantages over the more commonly used visual search task. Firstly, it allows the allocation of attention between two competing stimuli to be measured when those stimuli are not relevant to the participants' task. This makes it possible to study stimulus-driven effects of attention, while ruling out (or at least reducing) the influence of top-down variables which can cloud interpretation of data from the visual search task. Secondly, the visual search task does not gauge the precise spatial location of attention; rather it measures the latency to detect a target. The dot-probe task, on the other hand, allows inferences to be made about where attention is allocated, and potentially, how this changes across different presentation times.

Based on the previous work using the visual search task that has demonstrated an attentional bias towards the location of angry faces (Öhman et al, 2001; Fox et al, 2000; Eastwood, Smilek, & Merikle, 2001), a similar bias could be predicted in the present experiment. However, the dot-probe task has, to date, overwhelmingly suggested that a bias towards threat-related information (including angry faces) exists, but is only evident in high-anxious individuals (Mogg & Bradley, 1999; Mogg, Bradley, De Bono, & Painter, 1997; Bradley, Mogg, Falla, & Hamilton, 1998; Fox, 2002; Koster, Crombez, Verschuere, & De Houwer, 2004; although see Wilson & Macleod, 2003, discussed further in Chapter 5). Indeed, a study by Bradley et al (1997) using the dot-probe task suggests that while high-anxious individuals do direct attention towards the location of angry faces, low-anxious individuals actually avoid allocating attention to the location of angry faces. A similar result has been observed in the allocation of attention to threat-related words (MacLeod, Mathews, & Tata, 1986). Clearly these results contradict a number of studies that show evidence of an attentional bias towards threat-related information generally, and angry faces in particular, in the general population (Öhman et al, 2001a; 2001b; White, 1995; Eastwood et al, 2001; Fox et al, 2000).

This difference in findings could be because the allocation of attention in the dot-probe task is typically measured after the stimuli are presented for 500ms. It is widely assumed that this reflects the initial orienting of attention to the stimuli

(Bradley et al, 1998; Chen, Ehlers, Clark, & Mansell, 2002; Egloff & Hock, 2003). However, there is reason to suspect that measuring at 500ms may not represent the initial orienting of attention to the stimuli. This is because other research suggests that 500ms is adequate time for more than one shift in covert attention (Posner & Peterson, 1990). Thus, presenting the stimuli for a shorter duration (e.g., 100ms) could reveal a bias towards the angry face location. This result would support the work from the visual search task (e.g., Öhman et al, 2001) as well as help explain why previous studies using the dot-probe task (e.g., Mogg & Bradley, 1999) have only shown biases towards angry faces in individuals who measure high in anxiety.

Furthermore, based on the work by Ganel et al (2005) and Adams and Kleck (2005) who found that the processing of emotional expression was modulated by the processing of eye gaze, it is predicted that the allocation of attention to angry faces will be dependent on the associated gaze direction. Given that an angry face is more readily identified as such when it is associated with direct gaze than averted gaze (Adams & Kleck, 2005), the associated threat signal should be more pronounced when the angry face has direct gaze compared with averted gaze. Any observed bias towards angry faces should therefore be larger when the face has a direct gaze as opposed to when gaze is averted.

The current experiment also included trials in which happy faces were paired with neutral faces. The experiment could therefore identify whether any effects observed with the angry faces are unique to the angry face stimuli (negative selectivity) or whether they are present with emotional stimuli more generally (emotional selectivity). Based on previous experiments that include happy face stimuli (Bradley et al, 1997; Öhman et al, 2001; Fox et al, 2001) it was expected that results from happy/neutral trials would not follow those from angry/neutral trials.

Experiment 10

Method

Participants – Sixty undergraduate psychology students[16] (49 female, with a mean age of 20.5 years) from the University of Stirling took part for course credit.

Materials – Thirty pictures were taken from the Ekman and Friesen (1976) set of emotional expressions. The photographs comprised ten individuals (six females) each posing neutral, happy, and angry expressions looking straight into the camera. The external features of each of the faces were removed and the internal features were presented in a black rectangular frame. The image size (including the frame) measured 8.1˚ x 2.9˚ of visual angle. An averted gaze version of each of the faces was created in Adobe Photoshop by moving the pupils laterally until they were at the corners of the eyes. Half of the gaze-averted faces were made to look to the left and the other half were made to look to the right and this was done on a random basis with the restriction that there were equal numbers in each group. This gave a total of 60 photographs.

Each one of the 60 photographs was paired in Photoshop with a neutral face of the same identity with averted gaze. It was assumed that a face with a neutral

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[16] Allocation to the between subjects component of presentation time (PT) was not random. Initially 36 participants took part in the 500ms PT condition and one month later 24 participants took part in the 100ms PT condition. While this does not represent the ideal scenario for looking at differences in the allocation of attention across the two PTs there is no reason to suspect (although no way of knowing for sure) that the two groups differed from one another on any variable that might be influential to the results of the current experiment (e.g., anxiety – see Chapter 5).

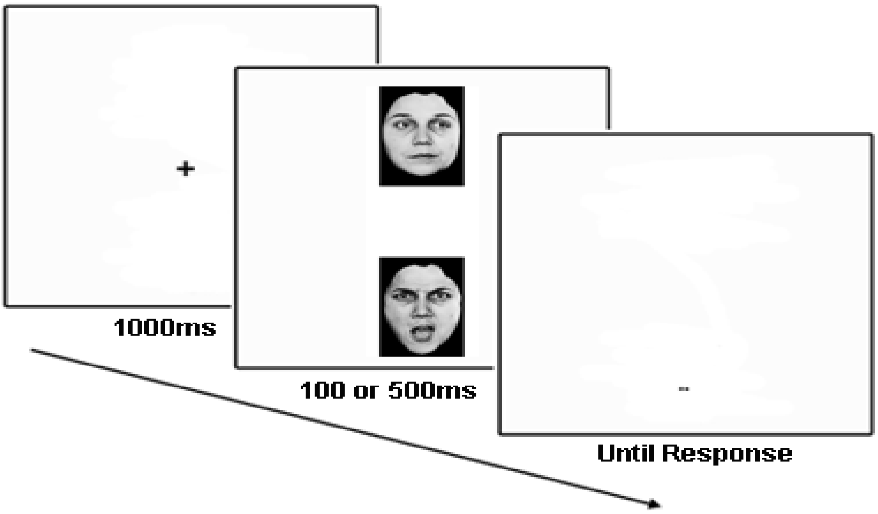

Figure 4.1: Illustration of the procedure from Experiment 1. A neutral face with averted gaze (top) could be paired with either an angry, happy, or neutral face with direct or averted gaze. Responses are made to the orientation of the probe as shown in the rightmost square.

expression and averted gaze would be least likely to attract attention compared with the other emotion and gaze combinations. The images were placed on a white background, one above the other, separated by 10.4˚ of visual angle from the centre of each picture and were viewed by participants from a distance of approximately 60cm (see Figure 4.1). Two versions of each face pair were created with the relative positions switched so that each face could appear in both locations (either top or bottom). Dot-probes comprised of two dots, each measuring 0.1˚ in diameter and separated by 0.5˚. They could be arranged either vertically or horizontally. Stimuli were presented on an iMac using the SuperLab experimental software. Responses were collected using a Macintosh Keyboard.

Design and Procedure – Participants saw a fixation cross for 750ms followed by a pair of faces for 100ms or 500ms[17] (depending on the group to which they were allocated) which were followed in turn by two dots. Participants' task was to identify whether the dots were horizontally or vertically oriented. The faces were therefore irrelevant to the task and participants were instructed to ignore them. Participants were asked to press one key (z) when the dots were horizontal and another key (m) when the dots were vertical. The dots remained on the screen for two seconds or until a response was made, whichever came sooner. Participants were given ten practice trials to familiarise themselves with the procedure and then 200 test trials with a break in the middle. These comprised twenty trials in each of the eight conditions: two emotional expressions (angry or happy), two probe locations (the location of the emotional face or the neutral face), and two gaze directions (direct or averted). The remaining 40 trials contained pairs of faces of the same identity, each with neutral expressions and averted gaze. These were included to act as a baseline[18] in order to help determine which mechanisms (e.g., facilitation or inhibition) might be responsible for any observed attentional biases (Koster, Crombez, Verschuere, De Houwer, 2004). Test trials were presented in a new random order for each participant.

[17] A PT of 500ms is standard for many studies using the dot-probe task and is often assumed to measure the initial allocation of attention between competing visual stimuli (e.g., Mogg, Bradley, Miles, & Dixon, 2004). However, other authors looking at the allocation of attention to gaze direction have found different patterns of attention when stimuli are shown relatively early (100ms) compared with relatively late (500ms) (e.g., Langton & Bruce, 1999).

[18] In this context, baseline trials are comprised of two identical pictures of the same face, both with averted gaze. Responses in the experimental trials can then be compared with responses in the baseline trials. If one stimulus is associated with RTs that are faster than baseline it is argued that its processing has been facilitated. On the other hand, if another stimulus is associated with RTs that are slower than the baseline it is argued that its' processing has been inhibited (Koster, Verschuere, Crombez, & Van Damme, 2005).

Results

		Face Pair			
		Angry/Neutral		Happy/Neutral	
Presentation Time	Gaze Direction	Angry	Neutral	Happy	Neutral
100ms	Direct	559 ± 17	557 ± 16	552 ± 17	542 ± 14
	Averted	545 ± 14	560 ± 17	564 ± 17	549 ± 18
500ms	Direct	612 ± 18	602 ± 19	601 ± 17	614 ± 22
	Averted	606 ± 18	593 ± 19	603 ± 21	623 ± 23

Table 4.1: Mean reaction times (ms) for identifying probes that appeared in a location previously occupied by an emotional (happy or angry) or neutral face, with a 100 or 500 ms presentation time and either direct or averted gaze (mean ± standard error).

The data analysis for the dot-probe task was based on reaction times for correct responses. Data from trials with errors were discarded (5% of data in both the PT conditions) and not analysed further. Data from participants who made more errors than 2.5 standard deviations from the mean were discarded (two participants, one from each of the between-subjects conditions, had an overall error rate of 24% and were not included in the analysis).

The interparticipant means of each individual's median response time in each experimental condition are displayed in Table 4.1. These data were entered into a 2 x 2 x 2 x 2 mixed ANOVA with three within-subjects factors of relative probe position (probe appears in the location of the emotional or neutral face), type of emotional expression (angry, happy), gaze direction (direct, averted), and a between-subjects factor of PT (100ms, 500ms). Responses tended to be faster in

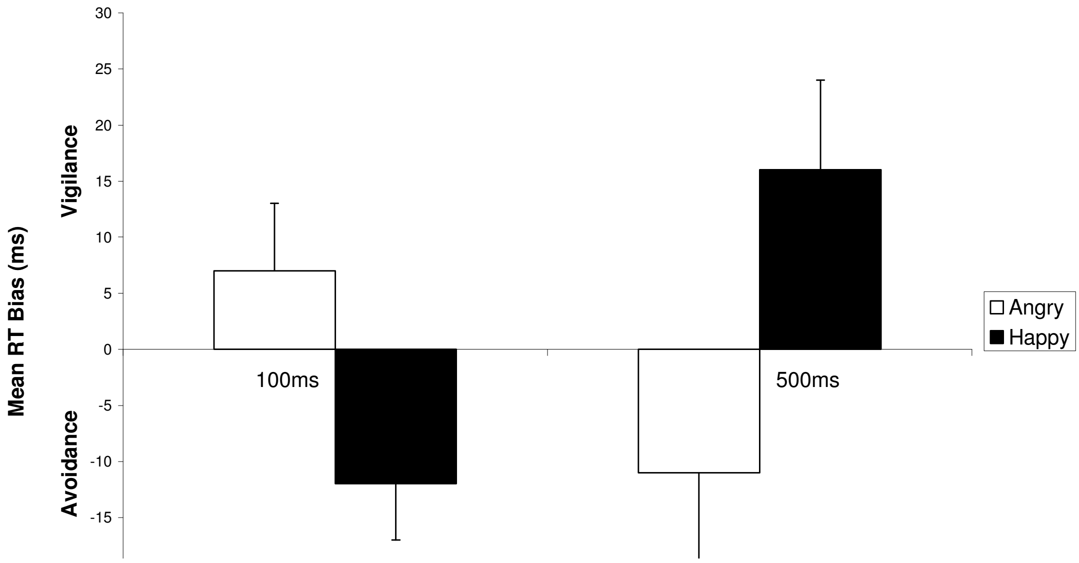

Figure 4.2: Mean attentional bias scores and standard errors for the angry and happy facial expressions in the 100ms and 500ms PTs.

the 100ms condition than the 500ms condition. This was supported by a significant main effect of presentation time, $F(1,56) = 4.11$, $p = .047$. This analysis also revealed a significant interaction between gaze and emotion, $F(1,56) = 4.52$, $p = .038$. For angry/neutral trials, this reflects faster responses overall (regardless of where the probe appears) when the averted gaze faces were presented (576ms) compared with direct gaze faces (582ms). Conversely, for happy/neutral trials, this reflects faster responses overall when direct gaze faces were presented (577ms) compared with averted gaze faces (585ms). However, simple main effects analysis revealed that neither of these individual effects were significant ($F<3.1$). This was the only interaction from the overall analysis in which gaze influenced response times.

There was also a marginally significant interaction between emotional expression and PT, $F(1,56) = 2.92$, $p = .093$, which was subsumed under a significant 3-way interaction between relative probe position, emotional expression, and PT, $F(1,56) = 8.98$, $p = .004$. To clarify the nature of this interaction, a bias score was calculated for each type of emotional face pair, modifying the procedure of Macleod and Mathews (1988). The bias score was calculated by subtracting the mean RT to probes which appeared in the location of the emotional face from the mean RT to probes which appeared in the location of the neutral face. Positive values reflect attention towards the emotional face (vigilance) and negative values reflect attention away from the emotional face (avoidance). These bias scores are displayed in Figure 4.2.

A 2 x 2 repeated measures ANOVA of the bias scores with emotional expression as a within-subjects factor and presentation time as a between-subjects factor yielded a significant emotional expression x PT interaction, $F(1,56) = 8.979$, $p = .004$. (This result is equivalent to the three-way interaction with RTs). Comparisons of the bias scores against zero (zero = no attentional bias) at 100ms showed significant avoidance of the happy face (bias score = -12, $t(22) = 2.636$, $p = .015$, two-tailed) but no significant vigilance of the angry face (bias score = 7, $p > .2$). At 500ms there was significant avoidance of the angry face (bias score = -11, $t(34) = 2.13$, $p = .041$, two-tailed) and a trend towards vigilance of the happy face (bias score = 16, $t(34) = 1.732$, $p=.092$, two-tailed).

To clarify the interaction term further, t-tests were carried out on the differences in attentional bias scores between the two PTs. This revealed a significant decrease in bias score for the angry/neutral pair between the short and long PT (angry bias at 100ms = 7ms, angry bias at 500 ms = -11ms, $t(58) = 2.192$, $p = .033$, two-tailed) and a significant increase in the bias score for the happy/neutral pairs between the two PTs (happy bias at 100ms = -12ms, happy bias at 500ms = 16ms, $t(47) = -2.697$, $p = .01$, two-tailed) face pairs. This indicates that the biases for each face pair are different at 100ms compared to 500ms.

		Face Pair			
		Angry/Neutral		Happy/Neutral	
Presentation Time	Baseline	Angry	Neutral	Happy	Neutral
100ms	544 ± 14	552 ± 20	559* ± 20	559* ± 21	546 ± 23
500ms	610 ± 18	609 ± 16	598* ± 16	602 ± 16	618 ± 19

*Significantly different from baseline p<.05

Table 4.2: Mean reaction times (ms) for identifying probes that appeared in a location previously occupied by an emotional (happy or angry) or neutral face, with a 100 or 500 ms presentation time (mean ± standard error).

Although the above analysis does illustrate the direction of attentional biases it does not make clear whether apparent vigilance (for example, to the happy face at 500ms) is a result of facilitation of attention at its location, inhibition of the neutral face location, or both. In order to establish which mechanisms are responsible for the observed attentional biases at both the 100ms and 500ms PTs, the mean RTs from the four experimental conditions were compared with baseline RTs obtained from trials comprised of neutral-neutral face pairs with averted gaze. Responses faster than the baseline RT would indicate that facilitation (vigilance) was taking place at that location compared to baseline responding. Responses slower than the baseline would indicate inhibition (avoidance) at that location compared to baseline responding (Koster et al, 2004). Response times to identify the probe for each emotional expression condition collapsed across gaze direction are displayed in Table 4.2. In the 100ms condition the baseline was 544ms. In happy/neutral trials the mean RT to probes appearing in the location of the happy face (559ms) was significantly slower than the baseline of 544ms, $t(22) = 2.724$, $p=.012$ (two-tailed), whilst probes appearing in the location of the neutral face (546ms) attracted equivalent RTs to baseline ($p > .8$). For angry/neutral trials the mean RT to probes appearing in the location of the angry face (552 ms) was no different from baseline ($p > .15$) but the mean RT to probes in the location of the neutral face (559ms) was significantly slower than the baseline, $t(22) = 2.332$, $p = .03$ (two-tailed). To summarise, at the 100ms PT the use of this baseline measure suggests that with angry/neutral pairs, participants inhibit the neutral face location but do not show vigilance to the angry face. For happy/neutral pairs, however, there is evidence for inhibition of the happy face location but no vigilance for the neutral face.

In the 500ms condition baseline responding was 610ms. For angry/neutral pairs, responses to probes which appeared in the location of the neutral face (598ms) were significantly faster than baseline (610ms), $t(35) = 3.018$, $p = .007$ (two-tailed), but performance in all other conditions was equivalent to baseline (all $ps > .14$). At the longer PT there is therefore evidence for facilitation of attention to the neutral face location in angry/neutral pairs when comparing with the baseline, but no other attentional biases.

Discussion

Experiment 10 was primarily concerned with whether the allocation of attention to emotional facial expressions is modulated by gaze direction. It was predicted that there would be an attentional bias towards the location of the angry face, specifically at the 100ms PT, and that this bias would be more pronounced when it was associated with direct gaze compared with averted gaze. This prediction received partial support. Results revealed an attentional bias (albeit not significant) towards the location of the angry face at 100ms[19]. Statistically, this bias was independent of the associated gaze direction. However, closer inspection of the data in Table 4.1 suggests that while there may be an overall tendency in angry/neutral trials to orient attention to the angry face at 100ms, this trend is driven by the averted gaze faces and not, as predicted, by the direct gaze faces. In fact, the data for the direct gaze angry faces is not even in the predicted direction, showing a bias of -2ms away from its location. Thus, while there is some support for the notion that angry faces are associated with an attentional bias towards their location at 100ms, there is no evidence to support the specific hypothesis that angry faces with direct gaze are associated with a larger attentional bias when compared to angry faces with averted gaze.

More generally, the results from the current experiment suggest that the allocation of attention to emotional expressions (both angry and happy) is not modulated by their associated gaze direction. This is not consistent with results from Adams and Kleck (2005) and Ganel et al (2005) who found that the processing of emotional facial expressions is modulated by the associated gaze direction. However, their experiments were measuring the extent to which the perception of emotional facial expressions is modulated by gaze direction, whereas the current experiment was looking at the extent to which the allocation of attention to these stimuli is modulated. In this case, differences in how the stimuli are perceived do not equate to differences in the way attention is allocated to the stimuli, despite the fact that

[19] For clarification: Bias scores from angry/neutral trials show a numerical bias towards the location of the angry face. Comparison with baseline trials reveals that this bias arises from responses being significantly slower when the probe appears in the location previously occupied by the neutral, compared with the angry face. This suggests that although a bias is present it may be arising through inhibition of the neutral face location rather than facilitation of the angry face location. See text for a full discussion of this idea.

the various combinations of emotional expression and gaze direction communicate different signals.

The current experiment was also designed to measure whether the allocation of attention to emotional facial expressions proceeds in the same manner for both positive and negative facial expressions (emotional selectivity) or whether specific effects are observed with negative emotional expressions (negative selectivity). The data clearly show that the allocation of attention in angry/neutral trials did not proceed in the same manner as it did in happy/neutral trials. At the 100ms presentation time, responses in the happy/neutral trials revealed a bias towards the location of the neutral face. This pattern was the opposite of that seen with the angry/neutral trials. Furthermore, for both sets of emotional/neutral face pairs, by 500ms the patterns of bias were the exact opposite of those observed at 100ms. Attention apparently moved to the location of the neutral face in angry/neutral trials and to the location of the happy face in happy/neutral trials. These differences in processing support data from previous studies that have addressed this issue (Bradley et al, 1997; Öhman et al, 2001; Fox et al, 2001) and suggest that positive and negative stimuli are treated in different ways by the attentional system, with negative stimuli receiving priority for initial processing. However, from the current experiment it is not possible to say whether the effects seen with the angry faces would not also be seen with other faces that had a different negative emotional expression (e.g., sadness).

Traditionally, biases towards and away from stimuli in a pair in the dot-probe task have been termed, respectively, vigilance and avoidance (e.g., Bradley et al, 1998, Mogg et al, 2000). For the angry/neutral face pair the pattern of results just described would be interpreted as initial vigilance to the angry face at 100ms (albeit only a weak trend) followed by avoidance of the stimulus at 500ms. Indeed, the current results showing apparent avoidance of the angry face at 500ms replicate the findings of Bradley et al (1997) who found such an effect with low-anxious individuals. For the happy/neutral face pair the data are suggestive of initial avoidance of the happy face at 100ms followed by vigilance at 500ms. However, these data can be interpreted in another way if it is assumed that on each trial attention is initially allocated to the most threatening face on the screen. In angry/neutral trials this would be the angry face but on happy/neutral trials this would be the neutral face. An expressionless face with gaze directed straight at the viewer could be considered neutral in terms of the emotion that is displayed but the signal that this conveys could be considered hostile or, at the very least, ambiguous compared to a happy face. If this assumption is made then the pattern of data is identical in both the angry/neutral and happy/neutral trials with attention being initially allocated to the relatively threatening face at 100ms and then shifting to the other face by 500ms.

Thus, there are at least three ways of interpreting the advantage in RTs to probes appearing in the location of the neutral face in a neutral/happy pair over RTs to probes appearing in the location of the happy face in the same type of pair: avoidance of the happy face or vigilance to the neutral face (perhaps because it is relatively more threatening), or both. In standard forms of the dot-probe task there would be no way of choosing between these interpretations. All other studies assume that the neutral face (or neutral scene or word) plays an entirely passive role and that attention is either allocated to, or away from, the valenced stimulus. As Experiment 10 illustrates, it is not clear if differences in attentional bias are as a result of vigilance to one particular stimulus, avoidance of another, or both. One method that has been recently employed to try and tease these issues apart is the introduction of baseline trials which are comprised of neutral/neutral stimulus pairs (Koster et al, 2004; Koster et al, 2005). Response times in experimental conditions are then compared with the baseline response times. If, in a particular condition, responses to identify the target are faster than the baseline, this implies that these responses are facilitated by a mechanism allocating attention to the region. If, however, response times are slower than the baseline, this implies that attention serves to inhibit processing at the location of the probe.

Using the baseline to interpret the nature of the observed biases in Experiment 1 radically alters their interpretation. For example, with the angry/neutral stimuli in the 100 ms condition, the traditional method of computing attentional bias reveals a bias towards the angry face location (and hence away from the neutral face location) that would normally be interpreted as vigilance to the angry face. However, if the RT scores from these conditions are compared against the neutral/neutral baseline the data suggests that differences in responses to probes following angry/neutral trials are due to inhibition of the neutral face rather than facilitation of the angry face. This pattern is mirrored in the happy/neutral face trials with the apparent vigilance to the relatively more threatening face (neutral) being due to inhibition of the happy face location. The data therefore suggest that an early attentional bias towards threat may actually arise through the inhibition of the relatively least threatening stimulus rather than through the facilitation of the more threatening member of a stimulus pair. This highlights the problem of interpreting data in this paradigm (see Koster et al, 2004 for a more detailed exploration of these ideas). What is clear is that results that would traditionally have been taken as evidence of avoidance or vigilance have to be reinterpreted when a baseline condition is employed. Therefore, I echo the sentiments of Koster et al (2004) when they state that without a baseline measure from which comparisons can be made, inferences concerning attentional mechanisms in the dot-probe task are problematic.

The fact that all the biases were independent of the associated gaze direction suggests that for the initial allocation of attention to emotional expressions, the direction of gaze, and hence the direction in which the signal is being transmitted, does not matter in terms of the allocation of attention. This is consistent with Le Doux's (1996) view that stimuli relating to threat are first subjected to a 'quick and dirty' analysis before being processed more thoroughly. This view would predict that all threat-related emotional expressions would attract the same degree of initial processing and it would only be at a later stage (e.g., identifying the expression) that the direction of gaze would be taken into account. In this view it makes good 'evolutionary sense' to have a default setting whereby attention gets allocated to any potential threat quickly rather than take the chance that the stimulus is not actually a threat to you specifically.

The current study also raises a methodological consideration. The results provide evidence to challenge the widely held assumption that the presentation time of 500ms in the dot probe task measures the initial allocation of attention (Bradley, Mogg, Falla, & Hamilton, 1998; Mogg, Bradley, Miles & Dixon, 2004). There was clear evidence that the biases measured at 100ms were not the same as those measured at 500ms. The implication of this is that researchers using the dot probe task to study attention should choose a shorter presentation time than 500ms if they wish to measure the initial allocation of attention. While the current results do not rule out the possibility that the actual initial allocation of attention might be different from that measured at 100ms (i.e., it might arise earlier) it is more in line with other work looking at the allocation of attention in response to facial signals (e.g., Langton & Bruce, 1999).

Regardless of the mechanisms involved in the effect, the main finding from Experiment 10 is that emotional expression modulates the allocation of attention between competing faces and that this is not modulated by the associated eye gaze. However, one alternative explanation is that there may be a low-level perceptual confound in the pictures that is contributing to the effect (see Hansen & Hansen, 1988). For example, the images of happy faces tend to show more teeth than the angry or neutral images. Thus, it is possible that the allocation of attention could have been made on the basis of the presence or absence of this white patch (the teeth) in the picture. To test this possibility, Experiment 11 replicated Experiment 10 except it inverted all the stimuli (i.e., rotated them through 180˚). Inverting faces disrupts their normal processing but leaves the processing of lower-level features of the picture intact (Yin, 1969). It also disrupts identification of emotional expression at both long (Calder, Young, Keane, & Deane, 2000) and short (Prkachin, 2003) exposure durations. Thus, by inverting the pictures and again measuring how attention is allocated between the stimulus pair, the resulting data should indicate the extent to which the pictures themselves, as opposed to the emotional signals, were responsible for the observed effects (Eastwood, Smilek, & Merikle, 2001; Fox, et al, 2000).

Experiment 11

Participants – Forty undergraduate psychology students (32 female, with a mean age of 20.5 years) from the University of Stirling took part for course credit.

Presentation Time	Gaze Direction	Face Pair: Angry/Neutral		Face Pair: Happy/Neutral	
		Angry	Neutral	Happy	Neutral
100ms	Direct	569 ± 23	564 ± 19	562 ± 21	546 ± 19
	Averted	556 ± 16	563 ± 22	572 ± 21	555 ± 20
500ms	Direct	578 ± 19	598 ± 27	595 ± 28	585 ± 25
	Averted	574 ± 20	610 ± 23	615 ± 28	584 ± 22

Table 4.3: Mean reaction times (ms) for identifying probes that appeared in a location previously occupied by an inverted emotional (happy or angry) or neutral face, with a 100 or 500 ms presentation time and either direct or averted gaze (mean ± standard error).

Materials and Procedure – These were identical to Experiment 10 except the stimuli were inverted.

Results

Data from trials with errors were discarded and not analysed further (5% of data). Analysis of reaction times was based on median response times for each experimental condition. The interparticipant means of these medians are displayed in Table 4.3. These data were entered into a 2 x 2 x 2 x 2 ANOVA with three within- subjects factors of relative probe position (probe appears in location of emotional or neutral face), type of emotional face (angry, happy), gaze direction (direct, averted), and a between-subjects factor of PT (100ms, 500ms). This analysis revealed a significant interaction between relative probe position and emotion, $F(1,38) = 18.95$, $p < .001$, which was subsumed by a marginal 3-way interaction between relative probe position, emotion, and PT, $F(1,38) = 3.93$, p =

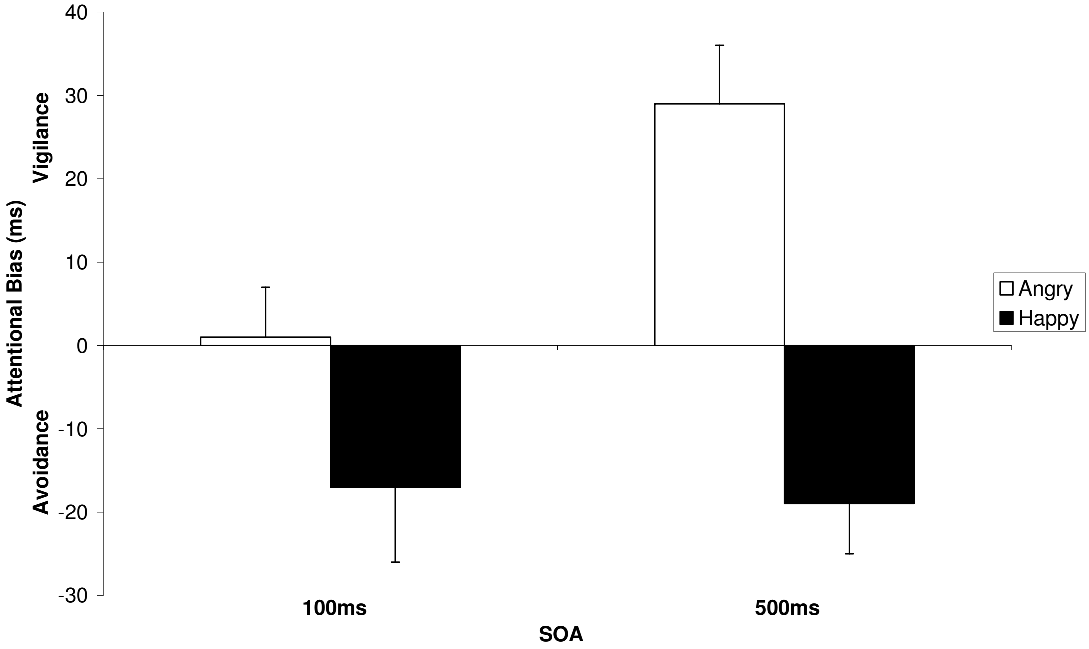

Figure 4.3: Mean attentional bias scores and standard errors for the angry and happy facial expressions in the 100ms and 500ms PTs.

.055. None of the effects interacted with gaze direction (p>.2). In order to clarify the nature of this 3-way interaction, bias scores were calculated using the procedure outlined in Experiment 10. These bias scores are displayed in Figure 4.3. Inspection of the data in this figure suggests that for angry/neutral trials, attention is biased towards the location of angry faces, particularly at 500ms. It also suggests that for happy/neutral trials, an overall bias towards the angry face attention is biased towards the location of the neutral face, regardless of PT. A 2 x 2 x 2 ANOVA conducted on these bias scores revealed a significant main effect of emotion, $F(1,38) = 18.95$, $p < .001$, showing an overall bias towards the angry face location on angry/neutral trials (bias = 15ms) and an overall bias away from the happy face location on happy/neutral trials (bias = -18). This was subsumed by a marginally significant 2- way interaction between emotion and presentation time,

$F(1,38) = 3.93$, $p = .055$, supporting the observation made with Figure 4.3. These results are equivalent to the effects observed with RTs. Comparison of these bias scores against zero (zero = no bias) for the 100ms PT showed marginally significant avoidance of the happy face (bias = -17ms, $t(23) = 1.88$, $p = .072$, two-tailed) and no bias for the angry face (bias = 1ms, $p>.8$). For the 500ms there was also avoidance of the happy face (bias = -19ms, $t(15) = 3.14$, $p = .007$, two-tailed) but in contrast with the 100ms PT there was significant vigilance towards the angry face location (bias = 29ms, $t(15) = 4.00$, $p = .001$, two-tailed).

To clarify the interaction term further, t-tests were carried out on the differences in attentional bias scores between the two PTs. This revealed a significant increase in the bias score for the angry/neutral pair between the 100ms and 500ms PTs (bias at 100ms = 1ms, bias at 500ms = 29ms, $t(38) = 2.77$, $p = .009$, two-tailed). The bias score for the happy/neutral face pair did not differ significantly between the two PTs.

Following on from the logic of Experiment 10, in order to establish which mechanisms are responsible for the observed attentional biases at both the 100ms and 500ms PTs the mean RTs from the four experimental conditions were compared to baseline RTs obtained from trials comprised of neutral-neutral face pairs. Responses faster than the baseline RT would indicate that facilitation (vigilance) was taking place at that location compared to baseline responding. Responses slower than the baseline would indicate inhibition (avoidance) at that location compared to baseline responding. Response times to identify the probe for each emotional expression condition collapsed across gaze direction are displayed in Table 4.4. In the 100ms condition the baseline was 560ms. In this condition all of the responses were equivalent to baseline. In the 500ms condition

		Face Pair			
		Angry/Neutral		Happy/Neutral	
Presentation Time	Baseline	Angry	Neutral	Happy	Neutral
100ms	560 ± 20	562 ± 19	564 ± 20	567 ± 20	550 ± 20
500ms	593 ± 23	576*± 19	604*± 24	604 ± 24	584 ± 23

*Significantly different from baseline p<.1

Table 4.4: Mean reaction times (ms) for identifying probes that appeared in a location previously occupied by an emotional (happy or angry) or neutral face, with a 100 or 500 ms presentation time (mean ± standard error).

baseline responding was 593ms. For angry/neutral pairs, responses to probes which appeared in the location of the neutral face (604ms) were marginally slower than baseline (593ms), $t(15) = 1.82$, $p = .089$ (two-tailed). In contrast, responses to probes which appeared in the location of the angry face (576ms) were marginally faster than baseline (593ms), $t(15) = 1.96$, $p = .069$ (two-tailed). Therefore, at the longer PT, the bias towards the angry face location seems to be due to facilitation of the angry face *and* inhibition of the neutral face stimuli in angry/neutral trials. There is no evidence of any bias involving the happy/neutral face pair when comparing with the baseline.

Discussion

The main purpose of Experiment 11 was to act as a control for Experiment 10. It is assumed that the pattern of attentional allocation seen in Experiment 10 was due to the emotional expressions on the faces. However, it is possible that some other property of the image that co-varied with emotion is responsible for the observed effects. In order to try and rule out any interpretation of the data which appealed to such low-level properties of the images, the stimuli in Experiment 11 were inverted but otherwise presented as they were in Experiment 10. Inversion is widely held to disrupt processing of emotional facial expressions yet leave intact low-level image properties (e.g., areas of particularly high contrast). Thus, if the results from Experiment 11 were the same as Experiment 10, despite inverting the faces, this would suggest the effects were due to the images themselves rather than the emotions being signalled (Eastwood et al, 2001; Fox et al, 2000).

The results from Experiment 11 go some way to rebuke this perceptual artefact explanation of the data. The pattern of attentional allocation to the stimuli was not the same as it was in Experiment 10. However, despite the differences between the results from the two experiments, the data clearly show the presence of attentional biases to the different images. Results from Experiment 11 show no bias in the angry/neutral pair at 100ms, but by 500ms, attention was in the location of the angry face. The bias scores for the same face pair when they were presented in the correct orientation in Experiment 10 showed initial bias to the angry face location followed by a bias to the neutral face location. For the happy/neutral pairs, data from Experiment 11 revealed a bias towards the neutral face location at both 100ms and 500ms. Whereas, the data from Experiment 10 showed an initial bias towards the neutral face location followed by a bias towards the happy face location.

Given that the results from Experiment 11 are different to those found in Experiment 10, it would be possible to argue that inverting the faces had the desired effect; namely, confirming that the results from Experiment 10 are not due to some low-level perceptual artefact of the pictures. However, given the fact that there were clear attentional biases with inverted stimuli in Experiment 11, it would be possible to argue that attention was responding to low-level properties of the stimuli. This argument would be damaging to any interpretation of Experiment 10 that tried to claim attention was being allocated on the basis of emotional expression.

However, it is possible that neither of these arguments gives an accurate account of the data. The assumption that inverting the emotional facial expressions disrupts their processing has empirical support (Calder et al, 2000; Prkachin 2003). However, identification of inverted emotional facial expressions is still well above chance, even when presented for 100ms (Prkachin, 2003). This being the case, it is possible that all inversion does is slow the allocation of attention to the emotional stimuli compared with its deployment to upright emotional facial expressions. Consistent with this view, comparison of Figures 4.2 and 4.3 reveals that, regardless of what might be driving attention, the pattern of bias at 100ms in Experiment 10 (Figure 4.2) is very similar to the pattern of bias at 500ms in Experiment 11 (Figure 4.3). In other words, the same pattern of bias is being shown across the two experiments, except in Experiment 11 it is delayed compared with Experiment 10.

One possible objection to this interpretation is that the data from Experiment 11 clearly show a bias in the happy/neutral face pair at 100ms and no bias in the angry/face pair at the same PT. If the data from Experiment 11 really do reflect an identical, but retarded allocation of attention to inverted expressions then this bias needs to be accounted for. An implicit assumption of inverting the emotional facial expressions as a control is that inversion will affect all of the stimuli equally. However, this does not appear to be the case. Prkachin (2003) asked participants to identify various emotional expressions (including angry and happy) when they were either upright or inverted. Inversion led to poorer performance overall but angry faces were more difficult to identify than happy faces (*A*' of 0.7 compared with 0.92[20]). Given that the processing of happy faces is not as badly disrupted by inversion as the processing of angry faces, this could account for the existence of a bias in the happy/neutral pair at 100ms without there being any bias in the angry/neutral pair.

The results from Experiment 11 therefore do not rule out the possibility that the emotion being signalled in the image continues to influence the allocation of attention when it is inverted. Combined with the evidence that inversion disrupts the processing of different emotions disproportionately (Prkachin, 2003), this raises doubts about the utility of inverting emotional facial expressions to act as control stimuli when investigating the relationship between attention and emotion. At the very least, it highlights the fact that the interpretation of data from such experiments is potentially not as straightforward as is usually assumed (Eastwood et al, 2001; Fox et al, 2000).

The chapter now returns to investigating the relationship between attention, gaze direction, and emotional expression in upright faces. Experiment 10 showed that emotional facial expressions influence the allocation of attention, and this effect was not modulated by the associated direction of gaze. However, the lack of any effect with gaze direction was shown when emotional faces were paired with neutral faces. Thus, the emotional expression would have been a particularly salient feature relative to gaze direction, constituting a much larger perceptual difference. This larger perceptual difference could account for why the allocation of

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[20] *A*' is a measure of signal detection sensitivity. An *A*' score of 1 would suggest the target could be detected perfectly whereas an *A*' score of 0.5 would suggest detection was at chance level.

attention to facial stimuli was modulated by emotional expression and not by gaze direction. The following experiment tried to overcome this problem by presenting face pairs which were always of the same emotion (e.g., two angry faces) and differed only in the gaze direction they adopted (direct or averted). This allowed investigation of the specific effects of gaze at each of two emotions (anger and fear). In line with the prediction from Experiment 10, it was expected that angry faces with direct gaze should be associated with an attentional bias at their location when paired with an angry face with averted gaze. This would be consistent with previous work showing that the perception of anger is facilitated when it is associated with direct gaze compared with averted gaze (Adams & Kleck, 2005).

In the current experiment, fearful faces replaced happy faces as control stimuli. In Experiments 10 and 11, happy faces were used to ensure that any effects arising from angry faces could not be attributed to emotional faces more generally. The happy faces served their purpose in this respect, showing that attention is allocated in a different way to happy faces than it is to angry faces. However, since a happy face is a positive emotional expression and an angry face is a negative emotional expression, this still leaves the possibility that the pattern of attentional allocation associated with angry faces may be common to that seen with other negative emotional expressions. Therefore, in Experiment 12, trials were presented in which fearful faces appeared in order to assess the extent to which any effects seen with angry faces are specific to those faces or if they are seen with negatively valenced faces more generally.

Experiment 12 also contained trials with pairs of neutral faces. This gave an opportunity to assess the influence of gaze direction on the allocation of attention when it is independent of emotion. Previous evidence suggests that direct gaze

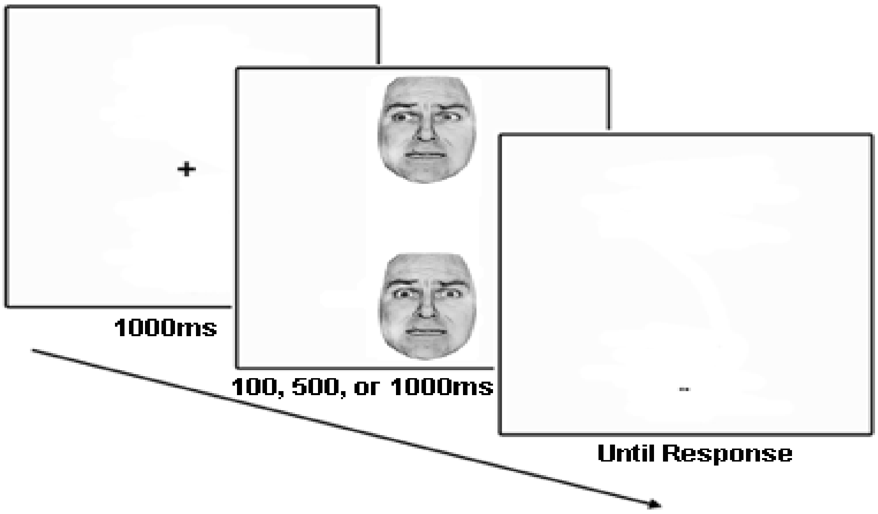

Figure 4.4: Illustration of the procedure used in Experiment 3. Face pairs were the same emotion (angry, fearful, or neutral), one with direct gaze and one with averted gaze. Responses were made to the orientation of the probe (vertical or horizontal) as shown in the rightmost square.

draws attention to its location (von Grünau & Anston, 1995; Senju et al, 2005) and that once direct gaze has been attended, it is particularly difficult to disengage from (Senju & Hasegawa, 2005). A bias towards the location of the direct gaze face was therefore expected.

Experiment 12 also sampled the allocation of attention at a longer presentation time of 1000ms as well as at those of 100ms and 500ms that were sampled in Experiment 10. Extending the time period in which attention is measured increases the chances of measuring any effects of attention that may arise as a result of the presentation of the experimental stimuli.

Experiment 12

Participants – Twenty-five undergraduate psychology students (22 female, with a mean age of 19.5 years) from the University of Stirling took part for course credit.

Materials and Apparatus – These were identical to Experiment 10 except the happy face stimuli were discarded and replaced with a further ten pictures from the Ekman and Friesen (1976) set. These pictures were of the same individuals used in Experiment 10 except they had fearful facial expressions. The gaze direction of these photographs was manipulated using Adobe Photoshop in the same manner as Experiments 10 and 11 so that there were two versions of each photograph; one gazing directly at the viewer, and one with gaze averted. In a change from the first two experiments the emotional faces were not paired with neutral faces. Instead, the direct and averted gaze versions of each of the emotional faces (angry and fearful), as well as the neutral faces, were paired together to yield face pairs which were identical in all respects except for gaze direction (see Figure 4.4). In common with Experiments 10 and 11, these faces were resized to measure 8.1˚ x 2.9˚ of visual angle and placed on a white background, one above the other, separated by 10.4˚ from the centre of each picture. Two versions of each face pair were created with the relative positions switched so that each face could appear in both locations (either top or bottom). Stimuli were presented on a Tatung 17" monitor with a Viglen PC with a Pentium III processor using E-prime software. Responses were collected on a serial response box (Psychology Software Tools, model # 200A).

Procedure

Participants were seated 80cm from the monitor with distance kept constant by means of a chinrest. Instructions made clear the need to try and make no eye movements while completing the task (i.e., fixate in the centre of the screen) and that the faces appearing before the probes on each trial were to be ignored. There then followed 16 practice trials with on-screen accuracy feedback after each trial and verbal feedback about the need to respond as quickly as possible. On

	Face Pair					
	Angry		Fearful		Neutral	
PT	Direct	Averted	Direct	Averted	Direct	Averted
100ms	549 ± 12	574 ± 15	551 ± 9	565 ± 15	578 ± 15	545 ± 11
500ms	538 ± 13	539 ± 14	546 ± 13	543 ± 16	534 ± 14	528 ± 12
1000ms	528 ± 14	556 ± 17	532 ± 12	545 ± 15	540 ± 14	541 ± 14

Table 4.4 – Mean reaction times (ms) for identifying probes that appeared in a location previously occupied by an angry, fearful or neutral face, with direct or averted gaze at 100ms, 500ms, or 1000ms PTs (mean ± standard error).

successful completion of the practice block, participants went through 192 experimental trials separated into two blocks with a break in the middle. These trials were comprised of eight from each of the 18 experimental conditions (144) and 16 from each of three baseline conditions (one baseline for each PT). These trials were presented in a new random order for each participant.

Results

The analysis was based on reaction time data for correct responses. Data from incorrect trials were removed (6.6% of data) and not analysed further. The data from one participant was removed for making more errors than 2.5 SDs above the mean. The interparticipant means of the median data from each experimental condition are displayed in Table 4.4. A 3 (emotional facial expression: neutral, angry, or fear) x 2 (gaze: direct or averted) x 3 (presentation time: 100ms, 500ms, or 1000ms) repeated measures ANOVA was conducted on the data.

As can be seen from Table 4.4, responses in the 100ms PT condition were slower than in the 500ms and 1000ms conditions. This is supported by a significant main

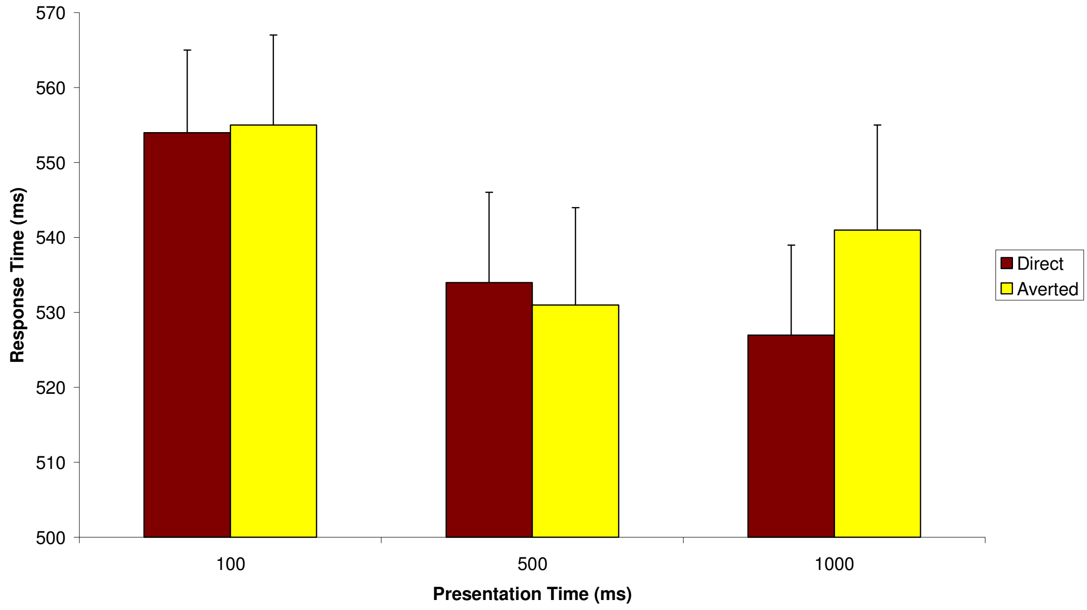

Figure 4.5: Mean response times and standard errors to respond to the identity of probes that appeared in the location of faces with either direct or averted gaze at each of three presentation times (100ms, 500ms, 1000ms).

effect of presentation time, $F(2,46) = 5.23$, $p = .009$. This was subsumed under a significant 2-way interaction between gaze and presentation time, $F(2,46) = 3.56$, $p = .036$. This interaction is shown in Figure 4.5 and inspection of this figure suggests that the interaction is due to responses in the direct gaze condition being faster than the averted condition at 1000ms, but being equal at the other two PTs. This is supported by simple main effects analysis which indicates that the effect of gaze is only significant at the 1000ms PT, $F(1,69) = 4.22$, $p<.05$. There was also a significant interaction between emotion and gaze, $F(2,46) = 4.12$, $p = .023$. This interaction is shown in Figure 4.6. Inspection of this figure shows that, for angry emotional expressions, there were faster responses to probes that appeared in the location of faces with direct gaze compared with faces with averted gaze. Simple main effects analysis shows that the difference in response times between trials with direct and averted gaze was only significantly different in the angry face trials,

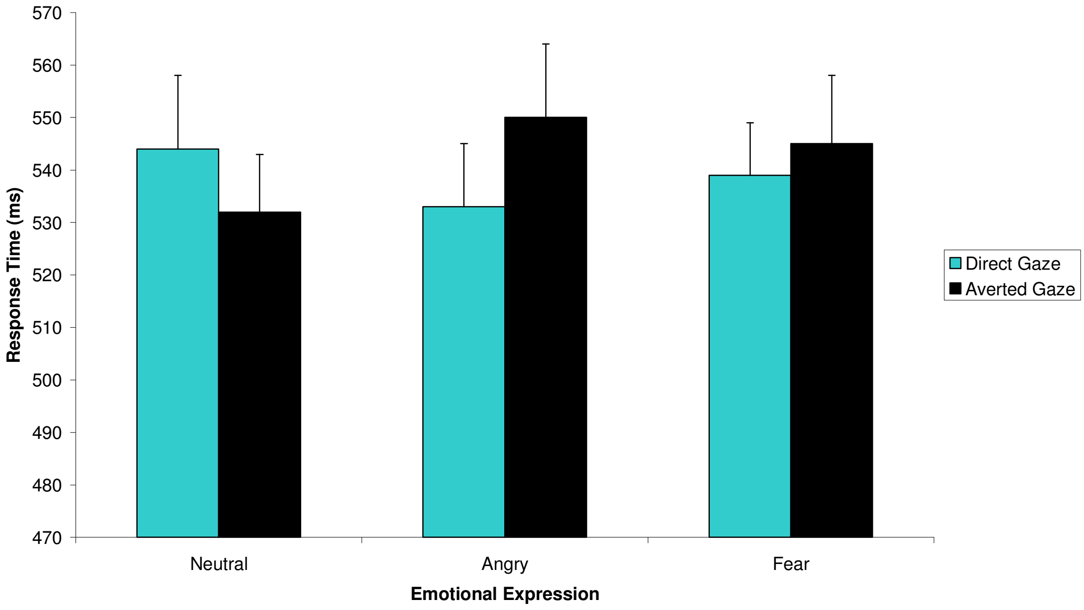

Figure 4.6: Mean response times and standard errors to respond to the identity of probes that appeared in the location of a neutral, angry, or fearful face, with either direct or averted gaze.

$F(1,69) = 4.92$, $p<.05$. No other effects approached significance (all ps>.1). Once again, RTs in experimental conditions were compared with baseline responding. However, in all cases, RTs did not differ from baseline.

The two interactions reported above are giving conflicting information concerning how attention is allocated to the different stimuli in this experiment. The interaction between emotion and gaze direction suggests that there is a bias towards the angry face with direct gaze, and that this bias is independent of PT. However, the interaction between gaze and PT suggests that there is a bias towards the location of direct gaze and that this bias is independent of emotional expression. In order to help clarify these discrepant findings, and given that predictions were made about the way gaze direction would influence the allocation of attention to each of the emotional faces separately, three 2 x 2 ANOVAs were conducted on the data to assess the influence of PT and gaze direction at each of the three levels of emotion.

Firstly, for the angry faces, this analysis revealed a main effect of gaze direction such that responses to identify probes were quicker when the probes appeared in the location of direct gaze faces (538ms) compared with averted gaze faces (556ms), $F(1,23) = 4.78$, $p = .039$. It also revealed a main effect of PT, $F(2,46) = 3.58$, $p = .036$. Post hoc tests confirmed that responses in 100ms PT condition (561ms) were slower than those made in the 500ms condition (538ms, $p = .006$) and those made in the 1000ms condition (542ms; $p = .082$). Secondly, for the fearful faces this analysis revealed no effects or interactions (all $ps>.2$). Finally, for the neutral faces this analysis only revealed a main effect of PT, $F(2,46) = 5.09$, $p = .010$. In keeping with the data from the angry face trials, post hoc tests confirmed that responses in the 100ms PT condition (561ms) were slower than those in the 500ms condition (531ms; $p = .005$) and those made in the 1000ms condition (541ms; $p = .053$). No other effects or interactions approached significance ($ps>.1$).

Comparing the responses in the angry face trials against baseline responding suggests that the attentional bias towards the location of the direct gaze face is brought about through a combination of facilitation and inhibition; facilitation of the direct gaze face compared to baseline (8ms quicker) and inhibition of the averted gaze face compared to baseline (10ms slower). However, neither of these effects were significantly different from baseline (both $ps>.15$).

Discussion

Experiment 12 was designed to further illuminate the relationship between attention, gaze direction, and emotional facial expression. It diverged from Experiments 10 and 11 by ensuring that the only difference between the faces presented on each trial was gaze direction. This meant that Experiment 12 was more able to assess the effect of gaze direction on the allocation of attention to faces and how this interacts with emotional expression. Another difference from the previous two experiments was that an extra presentation time of 1000ms was added to allow a longer time window for any potential effects to arise.

For angry face trials, it was predicted that attention should be biased towards the location of the faces with direct gaze. This prediction gained support. Responses to probes appearing in the location of angry faces with direct gaze were faster than when the probes appeared in the location of angry faces with averted gaze. This suggests the presence of an attentional bias towards the location of the angry face with direct gaze. Such a bias could be due to the specificity of the anger being directed back at the viewer. This is consistent with the results from Adams and Kleck (2005) that demonstrated an angry face is recognised as such more quickly when it is associated with direct gaze compared with averted gaze. It is also broadly consistent with the results from Experiment 10 which found that attention is initially allocated to the location of the relatively most threatening stimulus. However, unlike the results from Experiment 10 which found a bias towards the threat-related stimuli only at a PT of 100ms, the observed bias towards the angry face with direct gaze in the current experiment was independent of PT. Since Experiment 10 did not include a 1000ms PT, it is difficult to compare this aspect of the experiments too closely. This is especially true since closer inspection of Table

4.4 shows that despite the fact there is no interaction between the allocation of attention and PT, the effects at 100ms and 1000ms (25ms and 28ms respectively) are larger than those at 500ms (1ms) and clearly driving the effect. Accordingly, the current results do support the time-course of the effect in Experiment 10 in the sense that there is an initial bias to threat at 100ms that is not present at 500ms.

Fearful face trials were included to aid interpretation of the angry face data. While numerically, the data from the fearful face trials follow the same general pattern as those from the angry face trials, the effects do not approach significance. This supports the conclusion that the observed attentional bias towards the location of the angry face with direct gaze is specific to angry faces and not present for negative emotions more generally.

For neutral face trials it was predicted that attention should be biased towards the location of the face with direct gaze. There was no evidence to support this prediction. This result goes against previous work which has found that direct gaze is prioritised over the processing of averted gaze (von Grünau & Anston, 1995; Senju & Hasegawa, 2005; Senju et al, 2005). However, this result is only surprising if von Grünau and Anston's interpretation of their data is accepted. In their visual search task, they found that direct gaze targets embedded amongst averted gaze distractors were located more quickly than averted gaze targets amongst direct gaze distractors. They concluded that this result was due to attention being drawn to the location of direct gaze. However, as discussed in Chapter 1, an alternative interpretation of these data is that search through averted gaze distractors is faster than through direct gaze distractors. This alternative interpretation is supported by Senju and Hasegawa's (2005) data which show that once a face with direct gaze has been attended, it is relatively difficult to disengage attention from its location. This means that search through direct gaze distractors would be slowed. Thus, von Grünau and Anston's conclusion that direct gaze draws attention to its location may be flawed. If so, there is no reason to suspect that neutral faces with direct gaze will draw attention to their location in the dot-probe task; a task where participants are explicitly told that the faces are task-irrelevant.

Taken together, the results from the current experiment represent the first evidence that the allocation of attention to emotional expressions can be modulated by gaze direction. This suggests that when different faces are competing for visual attention, the face that is signalling the most imminent threat to the individual (as a function of direct gaze) will be selected prior to other faces. The current results also suggest that this effect is particular to angry faces and not negatively valenced faces more generally since the effect was not seen for fearful faces. Furthermore, the data show that attention is not allocated to the location of direct gaze faces. This is consistent with an alternative interpretation of von Grünau and Anston's (1995) data (described above). This finding does not undermine research suggesting that, once attended, gaze can both hold (Senju & Hasegawa, 2005) and shift attention (e.g., Langton & Bruce, 1999). However, it does question the validity of claims that direct gaze <u>draws</u> attention to its location (von Grünau & Anston, 1995; Senju, et al, 2005).

General Discussion

The three experiments in the current chapter were designed to investigate whether gaze direction modulates the allocation of attention to emotional facial expressions. Experiment 10 found that attention was initially (100ms) allocated to the relatively threatening member of the stimulus pair and that by 500ms attention had switched to the location of the happy face. The accompanying gaze direction on the face did not influence the allocation of attention. These results support the notion that facial information can be processed preattentively, and the information gleaned from this preattentive processing is used to guide attention to the location of threat (Öhman, 2002).

In Experiment 11, the faces that had been shown in Experiment 10 were inverted. Inversion disrupts the normal processing of faces while leaving the processing of lower-level stimulus features relatively intact. This experiment demonstrated that it was unlikely that the effects observed in Experiment 10 could be due to low-level perceptual artefacts that may have been present in the stimuli. However, it did highlight a potential problem for researchers looking at the relationship between attention and emotion. The data suggested that the emotional information in the facial images was still guiding attention even though the images were inverted. This is consistent with the evidence that although face inversion disrupts the processing of emotion, the emotional information is still processed (Prkachin, 2003). This suggests that future experiments looking at the allocation of attention to emotional facial expressions might consider using another method to control for low-level image characteristics. For example, presenting scrambled faces rather than inverted faces. Scrambled face pictures are images of faces that have had the pixels rearranged so that they no longer resemble faces (and as such do not communicate any emotional information) but maintain low-level image properties such as overall brightness and contrast. This would at least ensure that no emotional information is communicated in the images.

Experiment 12 was designed to test further the relationship between attention, gaze, and emotional expression. It differed from the previous two experiments by allowing gaze direction to be the only difference in the face pair shown on each trial. Thus, Experiment 12 equated the presentation of emotion on each trial (neutral, anger, or fear) and measured the influence of gaze direction on the allocation of attention with each type of facial expression. Experiment 12 also used an extra PT of 1000ms in order to investigate further the time course of any potential effects. Results suggested that gaze direction influenced the allocation of attention in angry face trials only. Responses to probes appearing in the location of angry faces with direct gaze were faster than when the probes appeared in the location of the same face with averted gaze. This suggests an attentional bias towards the location of the angry faces with direct gaze. A similar bias towards the direct gaze faces was not seen in either the fear face trials, or in the neutral face trials, suggesting that this result was unique to the angry facial expression. This is consistent with the results from Experiment 10, suggesting attention is allocated to the stimulus representing the greatest threat.

Across the three experiments, Experiment 12 was the only one to show that the allocation of attention to the emotional faces was modulated by gaze. It is likely that this is because Experiment 12 controlled the differences between faces within trials so that only gaze direction differed. The finding that the allocation of attention to emotional facial expressions is modulated by gaze direction suggests that information concerning both gaze direction and emotional expression is analysed preattentively. However, as the results from Experiment 10 show, this is limited only to circumstances in which gaze direction is all that differs between competing stimuli.

The finding that the allocation of attention to emotional expression can be modulated by gaze direction (Experiment 12) builds on the findings of Ganel et al

(2005) and Adams and Kleck (2005) who found that the perception of emotional facial expressions is modulated by the associated gaze direction. However, the current results are limited to showing that the modulation in the allocation of attention only occurs for angry facial expressions, and not for happy, fearful, or neutral expressions. This difference is likely to have occurred because preattentive processing may be biased to detect stimuli in the environment that correspond to potential threat (Öhman et al, 2001). Thus, given that the angry face with direct gaze presents a greater threat than an angry face with averted gaze, attention was drawn to its location. In contrast, while the perception of the other emotional expressions in the current experiments is known to be affected by gaze direction, the allocation of attention was not similarly affected.

Taken together, the experiments in the current chapter do support the notion that facial signals associated with threat (direct gaze, angry expressions) produce biases in attention. The intriguing finding in Experiment 10 that the biases towards the most threatening member of the stimulus pair were actually due to the inhibition of the least threatening member of the pair were not shown in Experiments 11 and 12. This is perhaps not surprising given the differences in methodology between the three experiments. However, the notion that the allocation of attention to threat works by inhibiting the processing of less threatening stimuli merits further investigation. What is evident is that the use of baseline trials in the dot-probe task is crucial if the precise mechanisms driving any effects are to be explored.

The data from the current chapter also provide evidence against the claim that only one face can be processed at a time (Bindemann et al, 2005). All three experiments presented evidence that emotional information from more than one face was processed in parallel. These experiments demonstrate the presence of attentional biases towards the location of emotional expressions at a PT of only 100ms. This PT is not long enough for volitional biases towards these stimuli to arise (Driver et al, 1999) which suggests that both faces were processed simultaneously and attention was automatically allocated to the one representing the relatively higher threat. At the very least these data suggest an amendment to Bindemann et al's (2005) theory to incorporate the current evidence that gaze and emotion information can be extracted in parallel from at least two faces simultaneously.

A logical next step for the work in this chapter would be to look at how the relationship between attention, gaze direction, and emotion is modulated by individual differences in anxiety. Anxiety is known to influence the way attention is allocated to emotional facial expressions (Mogg & Bradley, 1998), with those measuring high in anxiety demonstrating heightened sensitivity to threat-related stimuli in general, and those low in anxiety showing no such biases. Therefore, studying individuals with either high or low levels of anxiety and varying the relative threat of the stimulus as a function of gaze direction, should reveal differences in the way such stimuli are processed. This is addressed in the following chapter.

In summary, the current chapter investigated the relationship between attention, gaze direction, and emotional facial expressions. Across Experiments 10 and 11 there was evidence that the allocation of attention to faces is modulated by emotional facial expression, but not by gaze direction. However, Experiment 12 revealed that the processing of gaze direction can interact with the processing of angry expressions when attention is being allocated. This suggests that under certain circumstances attention is allocated on the basis of the facial signal (a combination of emotional expression and gaze direction) rather than purely on the basis of emotional expression. The next, and final, experimental chapter, follows on from the work in the current chapter by looking at the relationship between attention, eye gaze, and emotional expression, as a function of anxiety.

Chapter 5

Effects of Facial Signals on the Allocation of Attention to Faces in Anxiety

The main goal of Chapter 4 was to investigate the relationship between emotional facial expressions, gaze direction, and attention. There is previous evidence to suggest that the perception of emotional facial expressions is modulated by the associated gaze direction (Ganel et al 2005; Adams et al, 2003; Adams & Kleck, 2005). Results from Chapter 4 provide clear evidence that emotional expression can influence the allocation of attention to faces but also shows that gaze direction only modulates this effect for angry faces. The current chapter pursues this line of inquiry further by looking at the relationship between emotional facial expression, gaze direction, and attention, as a function of the participants' level of anxiety.

Anxiety is a negative affect that is closely related to fear. Like fear, it is associated with feelings of tense anticipation of a threatening event. However, fear-related responses occur to specific dangers and these responses end when the danger is no longer present. In contrast, the perceived threat in anxiety is vague and the person may have trouble identifying the source of their unease. This means that anxiety can be a chronic condition which is associated with constant worry about the existence of potential dangers in the world (Rachman, 1998).

Numerous studies have shown that anxiety is associated with attentional biases to threat-related information, not present in non-anxious matched controls (Mathews & MacLeod, 1985; Mogg, Mathews, & Weinman, 1989). MacLeod, Mathews, & Tata (1986) developed the dot-probe task (described in Chapter 4) to study the nature of attentional biases in anxiety. Using this paradigm they presented anxious and non-anxious individuals with pairs of neutral words (e.g. carpet - letter) for 500ms. On critical trials one of the neutral words was replaced by a threat-related word (e.g. cancer) and the allocation of attention to these words was measured by response times to identify a probe that appeared in one of the locations previously occupied by the words. MacLeod et al found that anxious individuals were faster to respond to probes that replaced threat words than neutral words, in comparison with 'normal' controls.

Subsequent work has shown that attentional biases towards threat-related information are not restricted to clinically anxious individuals but can also be observed in non-clinical individuals who measure highly on scales of anxiety. For example, Koster, Verschuere, Crombez, & Van Damme (2005) used the dot-probe task to measure the allocation of attention to images that could be of high-threat value (e.g. a mutilated body), mild-threat value (e.g. a man with a gun), or neutral (e.g. a household object). Results showed that when the images were presented for 100ms and 500ms, both low and high trait anxious[21] individuals demonstrated an attentional bias towards the location of the high-threat pictures. However, a bias towards the location of the pictures with mild-threat value was seen only in high-anxious individuals. This suggests that high-anxious people are particularly sensitive to threat, resulting in relatively innocuous stimuli being treated as if they were threatening (Mogg & Bradley, 1998).

Such anxiety-dependent differences in the processing of threat-related visual stimuli are also observed with angry facial expressions. Wilson and Macleod

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[21] Trait anxiety refers to a relatively enduring individual difference in the way in which people perceive and respond to the world. State anxiety, on the other hand, is a response to specific threatening episodes and thought to endure for only a limited time after the disappearance of the threat (Rachman, 1998).

(2003) presented participants with pairs of faces containing one angry face and one neutral face, and measured the allocation of attention between the faces using the dot-probe task. Crucially, the angry face varied in the intensity with which the angry emotion was being communicated. By morphing the original angry face with a neutral face of the same identity, Wilson and Macleod produced four distinguishable versions of the same face with different anger intensities: very low, low, moderate, and high. With a presentation time of 500ms, results showed that both low and high trait-anxious individuals had a bias towards the location of the high-threat face and away from the location of the low-threat face. However, in line with the results from Koster et al (2005), high-anxious individuals also showed a bias towards the location of the moderately threatening images whereas the low-anxious individuals did not.

Mogg and Bradley's (1998) cognitive-motivational theory identifies two distinct mechanisms to explain how the allocation of attention to threat is modulated by an individual's level of anxiety. The first is the Valence Evaluation System (VES), whose primary role is to assess the threat value of stimuli in the environment. Information from this system is passed on to the second mechanism, the Goal Engagement System (GES). This, in turn, responds to the nature of the information coming from the VES. If this information suggests the presence of a stimulus with a high threat value, then current goals are interrupted and attention is oriented to the threat. However, if the information suggests that no threat is present then current goals are maintained, the processing of positive stimuli is favoured, and relatively minor threat-related stimuli are ignored. Crucially, this theory suggests that the attentional response (as controlled by the GES) is a function of the input from the VES, which is a subjective evaluation of environmental threat. Accordingly, individual differences in the allocation of attention to threat are primarily based on trait anxiety, but are also influenced by other factors such as state anxiety, contextual variables, and previous experiences (Mogg & Bradley, 1998).

To summarise so far, anxiety is thought to influence the way in which attention is allocated to stimuli representing different levels of threat. High-anxious individuals have a relatively low threshold for what is interpreted as threatening and therefore will show biases towards the location of mildly threatening stimuli as well as highly threatening stimuli. On the other hand, low anxious individuals do show biases towards threat, but only when the stimuli are highly threatening (Koster et al, 2005, Wilson & Macleod, 2003; Mogg & Bradley, 1998).

This difference in the way low and high-anxious individuals respond to threat-related information provides the opportunity to assess individual differences in the allocation of attention to facial signals. As noted in Chapter 4, all previous work looking at the allocation of attention to facial stimuli has presented faces with gaze directed at the viewer. This is a problem because the resulting conclusions suggesting that attention is allocated to the location of angry faces for example (Öhman et al, 2001) may be dependent on the fact that the angry signal is directed at the viewer. Experiment 12 provided evidence that gaze direction can influence the allocation of attention to emotional expressions, but did so only under conditions in which both the presented faces were angry. Thus, it may be the case that gaze is analysed only when it is the sole feature that differs between the stimuli. In other words, processing gaze direction may be secondary to processing emotional expression and only conducted when analysis of emotional expression does not discriminate between the stimuli.

To test this possibility, the current experiment returned to the procedure of Experiment 10 which presented participants with neutral stimuli paired with emotional stimuli (angry and happy) that could have either direct or averted gaze. Crucially, the participants in the current experiment were identified as being low or high-anxious prior to testing. The influence of individual differences in anxiety on the allocation of attention to facial signals has been previously observed in gaze-cueing experiments. As described in Chapter 4, Hietanen & Leppänen (2004) measured the extent to which attentional shifting in response to observing another's averted gaze is modulated by the associated facial expression. Across seven experiments and with different emotional expressions (including anger, and fear) they found that attention consistently followed the direction of seen gaze, but this effect was not modulated by emotional expression. However, Mathews, Fox, Yiend, and Calder (2003) conducted a very similar study examining the influence of fearful expressions on the modulation of gaze cueing effects. Importantly, they divided their participants into low and high-anxious groups. They found that, independent of anxiety level, the latency to detect a target was reduced when the target location was congruent with the direction of the shift in gaze. However, their novel finding was that fearful faces produced larger cueing effects than neutral faces, but only in participants who were highly anxious. Thus, the allocation of attention in response to gaze cues is modulated by an interaction between the emotional status of the observer (i.e. anxiety level) and the emotional expression of the observed face.

Taken together, the extant data strongly suggest that individual differences in anxiety influence the way in which attention is allocated to faces as a function of emotional expression. Furthermore the work by Mathews et al (2003) suggests that information concerning emotion and gaze direction may be incorporated to provide a signal that shifts attention in a more compelling way than gaze direction on its own, but only in individuals with anxiety.

The experiment reported in this chapter examined how individual differences in anxiety influence the allocation of attention to facial expressions as a function of gaze direction. However, unlike the Mathews et al (2003) study, no difference in how high-anxious individuals respond to the emotional signals was expected. Rather, the low-anxious individuals might be expected to process the facial signals differently. It is possible to classify the angry face stimuli into two different categories of threat based on their gaze direction (direct gaze for high-threat and averted gaze for moderate-threat: following Wilson and MacLeod, 2003; Adams and Kleck, 2003). Given that high-anxious individuals are more sensitive to threat-related stimuli than low-anxious individuals (Koster et al, 2005; Wilson & Macleod, 2003; Mogg & Bradley, 1998; Mackintosh & Mathews, 1998), it was predicted that the high-anxious group would show a bias towards angry faces with both direct and averted gaze (i.e. to both the high and moderate-threat stimuli). However, the low-anxious individuals should only show a bias towards the location of angry faces with direct gaze and not angry faces with averted gaze (i.e. a bias towards the high-threat stimulus and not the low-threat one).

Furthermore, the current experiment also investigated the time-course of these effects as a function of individual differences in anxiety. As discussed in Chapter 4, much research using the dot-probe task assumes that the initial allocation of attention to stimuli can be measured following a presentation time of 500ms (Bradley, Mogg, & Millar, 2000; Chen, Ehlers, Clark, & Mansell, 2002; Egloff & Hock, 2003). However, as the results from Chapter 4 display very clearly, the allocation of attention at 500ms does not necessarily reflect the initial allocation of attention. Previous work looking at the time-course of attentional biases in anxiety has had mixed results. Mogg et al (1997) looked at the allocation of attention to threatening words at 100ms, 500ms, and 1500ms as a function of anxiety level and found a bias towards the location of the threat-related words in high-anxious participants, regardless of the exposure duration. No such effects were found in non-anxious controls. Similarly, Koster et al, (2005) looked at the allocation of attention to threatening pictures at 100ms, 500ms, and 1250ms as a function of anxiety level. They found a bias to high-threat pictures at 100ms regardless of anxiety level. However, only high-anxious individuals showed a bias towards mild-threat pictures at 500ms. Thus, in contrast to Mogg et al (1997), Koster et al demonstrated that the location of initial bias in anxiety is not necessarily measured when attention is probed at 500ms post stimulus onset. Together with the results from Experiment 10 of this thesis showing 'normal' individuals have a bias towards threat at 100ms post-stimulus onset, but not at 500ms, this suggests the initial allocation of attention should be measured earlier than 500ms. Accordingly, the current experiment probed the allocation of attention after PTs of 100ms and 500ms. Based on the results of Mogg et al (1997) and Koster et al (2005), it was expected that the predicted bias towards angry faces in high-anxious individuals will be present at both PTs. However, based on the results of Experiment 10, it was expected that low-anxious individuals will similarly show their predicted bias towards angry faces with direct gaze only at 100ms.

The current experiment also included trials in which happy faces are paired with neutral faces, following the procedure in Experiment 10. This allowed for the current experiment to identify whether any effects observed with the angry faces are unique to the angry face stimuli (negative selectivity) or whether they are present with emotional stimuli more generally (emotional selectivity). There were no specific predictions regarding the interaction between the processing of the happy faces and gaze direction.

Experiment 13

Method

Participants – Thirty-three undergraduate students from the University of Essex (17 female, with a mean age of 21 years) took part for course credit or payment of £3. Participants had previously been given the state trait anxiety inventory (STAI) (Spielberger, 1976) and had been invited to participate in this study if their trait anxiety score was less than or equal to 35 (low trait-anxious) or greater than or equal to 45 (high trait-anxious). Based on these criteria, 20 participants were classified as representing a low trait-anxious group and 13 representing a high trait-anxious group.

Materials and Apparatus – The materials in this experiment were identical to those in Experiment 10 in Chapter 4. The experiment was presented on a Macintosh G3 with a 15-inch monitor using SuperLab software. Responses were collected on a standard Macintosh keyboard.

Design and Procedure – This was identical to Experiment 10 except for a small number of changes as follows. Upon arrival, participants were given the ‘state’ section of the STAI. After completing this, a practice block of trials was given as in Experiment 10. The main body of the experiment contained twice as many critical trials as Experiment 10 (320) in order to accommodate the within-subjects factor of PT (100ms or 500ms), that had been a between-subjects factor in Experiment 10.

Furthermore, unlike Experiment 10, the current experiment did not include any neutral-neutral trials[22]. There were a total of four within-subjects factors and one between-subjects factor yielding a 2 (relative probe position: emotional or neutral face) x 2 (emotional expression: angry or happy) x 2 (gaze direction: direct or averted) x 2 (presentation time: 100ms or 500ms) x 2 (anxiety level: high or low) mixed design.

Results

The participant's state anxiety scores were subject to a median split. Since effects of anxiety are thought to be most pronounced when both levels of trait and state anxiety are high (Mogg & Bradley, 1998), and given that elevated levels of state anxiety are also thought to influence the allocation of attention to threat-related stimuli (Bradley et al, 2000; Barnard, Ramponi, Battye, & Mackintosh, 2005), the participants in the current study were only included in the analysis if their state anxiety score correlated with their trait anxiety score. Thus, in the following analysis, the high anxiety group represents individuals who have both high trait and state anxiety scores (n = 11) and the low anxiety group represents individuals who have both low trait and state anxiety scores (n = 14). Six individuals were excluded from the analysis due to having low levels of trait anxiety but high levels of state anxiety, and a further two individuals were excluded for having high levels of trait anxiety but low levels of state anxiety.

[22] This change means that baseline responding was not recorded. These trials were removed in order to accommodate time restrictions that were in place at the time of testing.

		Face Pair			
		Angry/Neutral		Happy/Neutral	
Presentation Time	Gaze Direction	Angry	Neutral	Happy	Neutral
Low Anxiety Group					
100ms	Direct	587 ± 35	603 ± 36	590 ± 34	576 ± 28
	Averted	586 ± 29	577 ± 35	603 ± 34	584 ± 30
500ms	Direct	584 ± 25	573 ± 25	586 ± 26	586 ± 30
	Averted	575 ± 27	579 ± 25	599 ± 28	566 ± 27
High Anxiety Group					
100ms	Direct	584 ± 40	616 ± 40	600 ± 38	600 ± 32
	Averted	580 ± 33	620 ± 39	600 ± 32	577 ± 34
500ms	Direct	589 ± 28	600 ± 28	591 ± 30	586 ± 34
	Averted	590 ± 30	598 ± 28	594 ± 31	584 ± 31

Table 5.1: Interparticipant means of median response times and standard errors (ms) to respond to the identity of a probe in each of the experimental conditions.

The interparticipant means of median reaction times for correct responses are displayed in Table 5.1. To simplify the analysis on these data, bias scores were created using the procedure outlined in Chapter 4. Data from trials with errors were discarded (5% of data) and not analysed further. A 2 (gaze direction) x 2 (emotional expression) x 2 (presentation time) x 2 (anxiety level) ANOVA was conducted on these bias scores and this revealed a significant main effect of emotion, $F(1,23) = 5.6$, $p = .027$, reflecting overall vigilance towards angry faces (12ms bias) and avoidance of happy faces (-13ms bias). The analysis also revealed a marginal effect of PT, $F(1,23) = 3.52$, $p = .073$, as well as a marginal

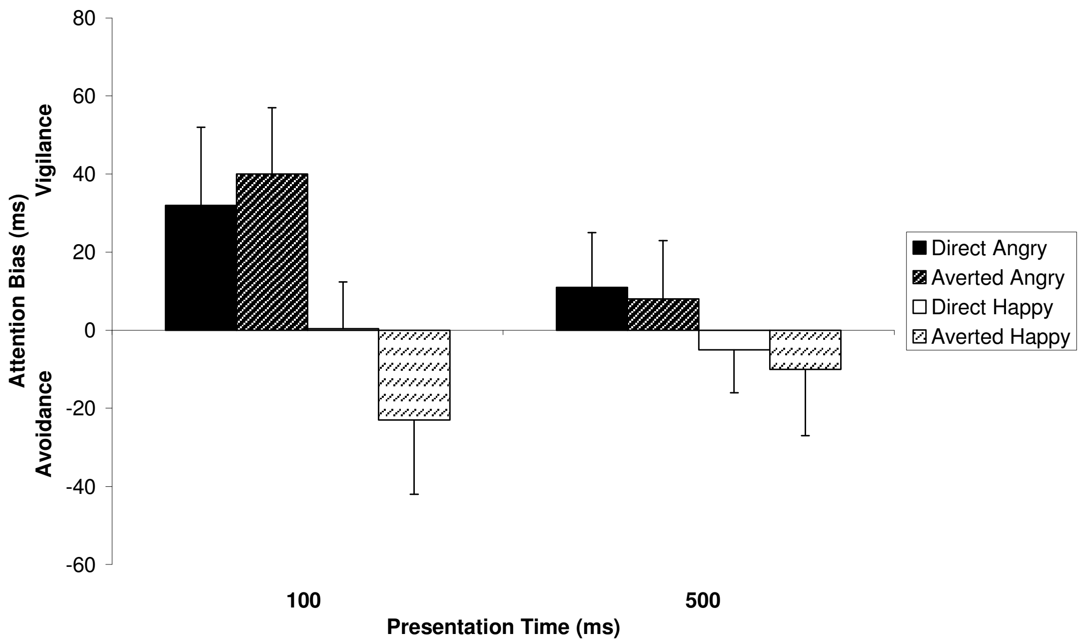

Figure 5.1: Mean attentional bias scores and standard errors for angry and happy facial expressions with both direct and averted gaze as a function of PT for the high-anxious participants.

between-subjects effect of anxiety level, $F(1,23) = 3.78$, $p = .064$. All of these effects are subsumed under a marginal 4-way interaction $F(1,23) = 3.61$, $p = .070$.

To further clarify this 4-way interaction, two separate 3-way ANOVAs were conducted; one for each between-subjects factor of anxiety. The bias data for the high-anxious participants are shown in Figure 5.1. Bias scores in angry/neutral trials suggest that attention was in the location of the angry face when the probe appeared. This observation is supported by a marginal effect of emotion ($F(1,10) = 4.13$, $p = .069$), suggesting vigilance towards the angry faces (bias = 23ms) and avoidance of the happy faces (bias = -9ms). This effect was independent of gaze direction. The analysis also revealed a marginal effect of PT, $F(1,10) = 4.45$, $p = .061$, reflecting overall vigilance to emotional stimuli at 100ms (bias = 12ms) but

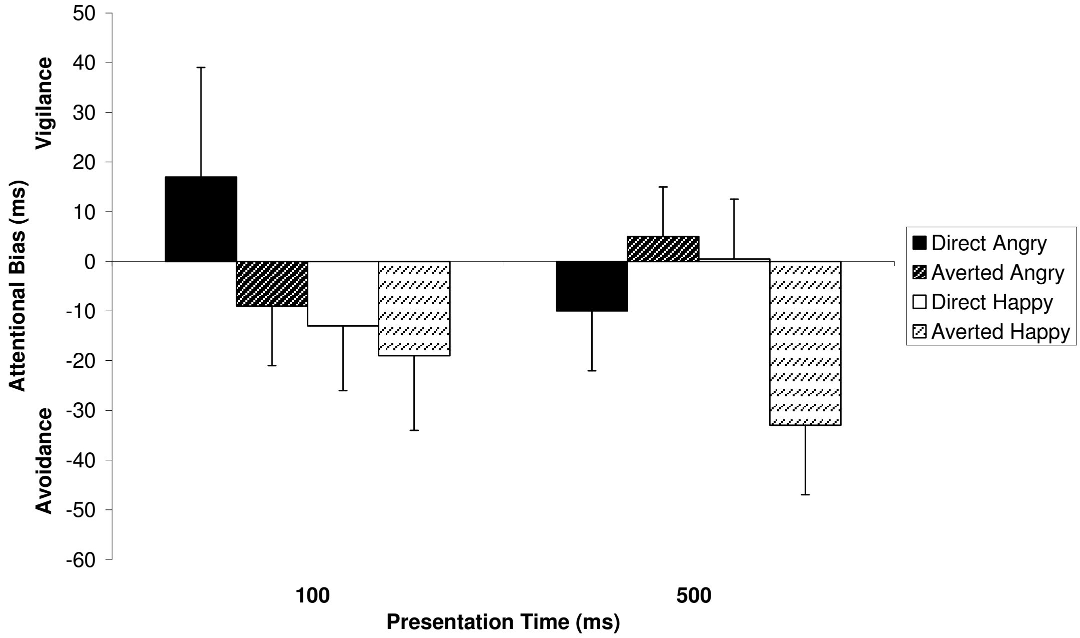

Figure 5.2: Mean attentional bias scores and standard errors for angry and happy facial expressions with both direct and averted gaze as a function of PT for the low-anxious participants.

not at 500ms (bias = 1ms). Inspection of the figure indicates that this effect at 100ms is driven by attentional biases to the angry faces. However, the interaction that this suggests did not reach significance ($p>.2$). Given the a priori predictions concerning the allocation of attention to threat, each of the bias scores in the angry/neutral trials was compared with zero (zero = no bias) using one-tailed tests in order to determine the nature of the attentional effects in each condition. These comparisons revealed marginally significant vigilance towards the direct angry face, $t(10) = 1.57$, $p = .074$, and significant vigilance towards the averted angry face, $t(10) = 2.34$, $p = .021$.

For the low-anxious participants the bias data are displayed in Figure 5.2. Inspection of this figure reveals a numeric trend suggesting the predicted vigilance towards the angry faces with direct gaze in the 100ms condition. A 3-way ANOVA revealed a marginal 3-way interaction between gaze, emotion, and PT, $F(1,13) = 4.08$, $p = .064$. In order to clarify the nature of the attentional biases for these data, each of the bias scores was compared against zero. This revealed that only the avoidance of averted happy faces at 500ms was significantly different from zero, $t(13) = 2.31$, $p = .038$ (two-tailed). The predicted vigilance towards angry faces with direct gaze was not significant, even with a one-tailed test ($p=.23$).

Discussion

The current experiment measured how individual differences in anxiety influence the allocation of attention to angry facial expressions that have either direct or averted gaze. It was predicted that high-anxious individuals should show a bias towards the location of angry faces regardless of presentation time or gaze direction. In contrast, it was predicted that low-anxious individuals should also show a bias towards the location of angry faces, but only those with direct gaze at the 100ms PT. Results partially supported these predictions with data from high-anxious individuals showing a bias in the allocation of attention towards angry faces. As predicted for the high-anxious individuals, this bias was independent of gaze direction and presentation time. However, despite data from the low-anxious individuals suggesting a trend following the predicted bias towards angry faces with direct gaze at 100ms, this trend did not reach significance.

These data are broadly consistent with previous research showing that anxious individuals are particularly prone to show biases in the way attention is allocated to threat-related stimuli (Bradley et al, 1997; Bradley et al, 2000; Koster, et al, 2005; Wilson & MacLeod, 2003). However, in the experiments by Koster et al (2005) and Wilson and MacLeod (2003) results suggested that both low and high-anxious individuals show an attentional bias towards stimuli classified as highly threatening, but only high-anxious individuals demonstrate an attentional bias to mildly threatening stimuli. The results from the current experiment do not entirely support the previous findings in this regard; although high-anxious individuals demonstrated a bias towards angry faces which was independent of threat value, low-anxious individuals did not show any bias towards the location of angry faces, irrespective of whether they had direct gaze or averted gaze.

One difference between the current results and those of Koster et al (2005) and Wilson and MacLeod (2003) is that the current results only demonstrated an attentional bias towards the threat-related stimuli in the high-anxious group at 100ms. However, the previous research showed such a difference was present at both 100ms for threat-related pictures (Koster et al, 2005) and 500ms for both pictures and angry faces (Koster et al, 2005; Wilson & MacLeod, 2003). Furthermore, 500ms is the most commonly used PT with the dot-probe task and it is at this PT that the most consistent effects are reported with high-anxious individuals (MacLeod et al, 1986; Bradley et al, 1997; Mogg et al, 2000). Thus the current failure to show clear effects at the 500ms PT is somewhat surprising. It is even more surprising given that the participants were only included in the current experiment if they rated highly on scales of both trait and state anxiety. In theory, this should mean they are more likely to show a bias towards the angry faces at 500ms (Mogg & Bradley, 1998).

Although there is no immediate explanation for this discrepancy, it serves to highlight the fact that by sampling the allocation of attention at 500ms, as is standard practice for researchers using the dot-probe task (Bradley et al, 1998; 2000; Mogg et al, 2004; Wilson & MacLeod, 2003), effects that arise and dissipate before 500ms will not be recorded. As is shown in the current experiment, and in

Chapter 4, not measuring attention at 100ms (or a similar PT below 500ms) would lead to fundamentally misleading conclusions about the way attention is allocated to emotional facial expressions in both anxious and non-anxious populations.

Nevertheless, the data from the current experiment are generally consistent with recent models of cognitive biases in anxiety which predict the occurrence of specific anxiety-related biases such that stimuli which represent a relatively low threat will recruit attentional resources in those individuals who are highly anxious (Mogg & Bradley, 1998; Mathews & Mackintosh, 1998). This was seen in the current study where high-anxious individuals demonstrated an attentional bias towards the location of the angry faces with averted gaze, as well as to the angry faces with direct gaze. However, a non-significant numeric trend aside, there was no evidence of an attentional bias towards the location of the angry faces in low-anxious participants. This is somewhat surprising given the prediction from Mogg and Bradley's (1998) model that even low-anxious participants should attend to stimuli which have a high threat value. It is even more surprising given Wilson and MacLeod's (2003) finding that both low and high-anxious individuals do indeed show an attentional bias towards the location of an angry face with direct gaze (in their so-called 'high-threat' condition). The conclusion that can be drawn from the low-anxious participants in the current experiment is that angry faces, even those with direct gaze, are not necessarily able to draw attention to their location. Even so, it is not clear why low-anxious individuals have shown an attentional bias to angry faces in some previous work (e.g. Wilson & MacLeod, 2003), and not in other work (e.g. this chapter; Bradley et al, 1997).

One possible explanation for the lack of predicted effects with the low anxious group could be that the current study did not separate the effects of repressors from other low anxious participants. Previous research has shown that individuals who are identified as being low in anxiety can be further classified as being 'genuinely' low in anxiety, or as repressors (Asendorpf & Scherer, 1983). Repressors are identified as being low in anxiety but high in defensiveness and affect inhibition, as measured by the Marlowe-Crowne Social Desirability Scale (Crowne & Marlowe, 1960). Importantly for the current study, they also show a different pattern of attentional bias compared with that seen in 'genuinely' low anxious participants. For example, Fox (1993) presented participants a dot-probe task with emotionally threatening and neutral words (500ms presentation time) and found that while high anxious participants showed a bias <u>towards</u> the location of the threat words, 'genuinely' low anxious showed no bias, and repressors showed a bias <u>away</u> from the threat words. While from this it is not clear how repressors might allocate their attention in response to viewing emotional faces, it is clear that the failure to screen for repressors in the current study might somewhat colour the interpretation of the data from the low anxious participants. Future experiments should aim to identify any repressors in the sample.

The current experiment was also designed to test whether any effects observed with angry faces are unique to the angry face stimuli (negative selectivity) or whether they are present with emotional stimuli more generally (emotional selectivity). Results clearly demonstrated that the allocation of attention in response to the presence of happy faces proceeded in a different manner to how it was allocated in response to the presence of angry faces. In fact, in contrast to the results with the angry face stimuli, there was evidence of avoidance of the happy face location. This supports the notion that attention is allocated to the location of negatively valenced stimuli in particular, rather than emotional stimuli more generally. However, this still leaves open the possibility that attention might be allocated to the location of negative expressions generally (e.g. fearful, sad, angry) and not just angry expressions in particular. However, given previous investigation of this issue, this seems unlikely (Bradley et al, 2000).

Along with the results of Experiment 10, the current results, especially those from happy/neutral trials, call into question the standard interpretation of results using the dot-probe task. Following the standard interpretation (Bradley, et al, 1997; Bradley, Mogg, Falla, & Hamilton, 1998; Bradley et al, 2000; Mogg, Phillippot, & Bradley, 2004) a bias away from the location of the happy face would be classed as avoidance of the happy face. This interpretation of the dot-probe task is based on the assumption that the other item in the stimulus pair (in this case a neutral face) does not influence the allocation of attention. However, it is possible that attention does respond to the neutral face. Leading from this, an alternative interpretation of these data would be that the apparent bias away from the happy face location is a result of vigilance to the neutral face rather than avoidance of the happy face. This interpretation seems plausible given the consistent finding that attention is allocated to the location of the most threatening image in a stimulus pair (Wilson & MacLeod, 2003, Chapter 4, this thesis). As discussed in Chapter 4, adopting this interpretation requires an understanding that a face with a neutral expression may be relatively threatening compared to a happy face, and as such, attention will be allocated to its location. Unfortunately, unlike the experiments reported in Chapter 4, responses from baseline trials were not collected in the experiments reported in this chapter. This means that for the current results, there is no way of choosing between these two potential interpretations. However, based on results from Experiment 10 it is likely that the bias observed in the happy/neutral trials was a result of vigilance to the neutral face rather than avoidance of the happy face.

Experiment 12 demonstrated that when participants are not selected on the basis of their anxiety level, gaze direction only influences the allocation of attention to emotional facial expressions when those expressions are angry, and only under conditions where gaze is the sole factor that differs between expressions. The results from the current chapter do not provide any more compelling evidence to suggest that gaze direction modulates the allocation of attention to emotional facial expressions. There was no evidence from the high anxious participants that the allocation of attention was dependent on the gaze direction on the face. Data from these participants suggested equivalent biases towards the angry faces regardless of gaze direction. However, there was a suggestion in the data from the low anxious participants that gaze direction might influence the allocation of attention. This was in the happy/neutral trials at 500ms where a bias was shown away from the location of a happy face with averted gaze. No such bias was shown in trials featuring happy faces with direct gaze. While it is not clear why this effect was found, it does suggest that gaze direction may be important in the allocation of attention to emotional facial expressions. However, future research would need to ascertain whether this is a robust effect, and if so, why it only applies to happy faces.

Despite this finding, the results from the current experiment support the results from Experiment 10 that the allocation of attention to angry expressions is not dependent on their gaze direction. This supports the idea that the initial allocation of attention is made on the basis of the most salient aspects of the face. Accordingly, when presented with two facial stimuli that vary in expression and gaze (as in Experiments 10 and 13), the expression information guides attention. However, when presented with two facial stimuli that vary only in gaze, and both are angry, an analysis of gaze direction is also performed in order to allocate attention. Consistent with the data, this suggests the attentional system makes use of available information in order to direct attention to the threat-related stimuli. This is in line with other work showing that the allocation of attention to threat-related stimuli is prioritised above the processing of other stimuli (Öhman et al, 2001).

As demonstrated in the current study, individual differences in anxiety influence the allocation of attention to threat. High-anxious individuals have a relatively low criterion for what is classed as a threatening stimulus and thus, are more prone to reveal biases towards such information. Low-anxious individuals, on the other hand, have a relatively high criterion and are less likely to show biases towards threat. As the threat-value of the stimulus increases, low-anxious participants are more likely to attend to it; however, the stimuli in the current experiment were not sufficiently threatening to reveal such a bias.

The fact that high-anxious individuals demonstrated a different pattern of orienting to low-anxious individuals is a standard finding in the dot-probe task (Bradley et al, 1997; Bradley et al, 2000; Mogg et al, 1997; Koster et al, 2005). Much of the focus of these research reports is on how an individual's anxiety level influences the way attention is allocated to threat-related stimuli. This is because recent accounts of anxiety suggest that biases in the processing of threat-related material are responsible for the development and maintenance of anxious states (Mogg & Bradley, 1998; Mathews & Mackintosh, 1998). However, recent work has given reason to suspect that the observed attentional biases to threat may be just part of wider, as yet unspecified, pattern of processing biases in anxiety. Tuller and Pinto

(2005) presented high and low-anxious participants with a five-minute video clip in which numerous anomalous changes occurred to people and objects (e.g. an actor changed identity between scenes). High-anxious participants reported significantly fewer of these changes than the low-anxious participants. This suggests that the two groups allocate attention in qualitatively different ways, even when the information being attended is not related to any specific threat. These findings merit further investigation given that anxiety is currently thought to be associated with atypical processing of threat rather than being a more generalised disorder (Mogg & Bradley, 1998, Rachman, 1998; Wilson & MacLeod, 2003).

In summary, the current experiment was designed to explore anxiety-related differences in the allocation of attention to emotional facial expressions as they varied in gaze direction. High-anxious individuals demonstrated a bias towards angry faces, regardless of gaze direction and PT. In contrast, low-anxious individuals did not demonstrate such a bias. This highlights the role of anxiety in how biases towards emotional stimuli manifest themselves. Similar effects were not shown with happy face stimuli, supporting the notion that attention is allocated to negative stimuli specifically, rather than emotional stimuli more generally. The experiment also highlights the fact that traditional approaches to measure the initial allocation of attention at 500ms will potentially miss effects that dissipate before this time window opens.

Chapter 6

General Discussion and Future Directions

The introductory chapter of this thesis laid out evidence to suggest that the relationship between faces and attention may be special in the sense that the processing of faces is prioritised over the processing of other types of visual stimuli. Furthermore, it went on to show that the way attention is allocated to a face depends on the signal it is communicating. This thesis has sought to examine the relationship between attention and different facial signals; first focussing on eye gaze (Chapters 2 and 3) and then looking at the interaction between gaze and emotional facial expressions (Chapters 4 and 5).

Previous research has suggested that the relationship between eye gaze and attention has three distinct properties. Firstly, attention can be drawn to the location of direct gaze (von Grünau & Anston, 1995, Senju et al, 2005). Secondly, attention can be held by direct gaze (Senju & Hasegawa, 2005). Thirdly, attention can be shifted away from the location of averted gaze (Friesen & Kingstone, 1998; Driver et al, 1999; Langton & Bruce, 1999). It has been suggested that the first and third of these effects are governed by automatic, stimulus-driven mechanisms (e.g. von Grünau & Anston, 1995; Driver et al, 1999). Chapters 2 and 3 set-out one of the main goals of this thesis which was to examine the boundaries of these two effects.

In Chapter 2 it was reasoned that if direct gaze does draw attention to its location as has been suggested (von Grünau & Anston, 1995, Senju et al, 2005) then, as a stimulus, it should be particularly difficult to ignore. A distractor interference paradigm was used to test this hypothesis. Experiments 1-3 found no evidence that direct gaze flankers were more difficult to ignore than flankers with eyes closed. These findings do not support the notion that direct gaze is prioritised for processing by the attentional system (von Grünau & Anston, 1995; Senju et al, 2005). Nevertheless, both types of flankers did interfere with the processing of the task-relevant centrally presented eye stimuli, a finding that runs contrary to the notion that capacity limits in face processing permit only one face to be processed at a time (Bindemann et al, 2005). This finding was confirmed in a fourth experiment. Further research is needed to investigate the circumstances that lead to an apparent inability to process more than one face at a time, as shown by Bindemann et al. However, data from experiments reported in Chapter 2 present a clear challenge to this position.

The experiments reported in Chapter 3 investigated the relationship between averted gaze and attention. They focussed on the effect that observing another's eye gaze has on shifting attention away from the face, and investigated in what sense this can be said to be automatic. In these experiments, participants were shown a pair of eyes that could be looking back at the viewer, looking at another stimulus on the screen, or looking in the opposite direction from that stimulus. Crucially, these images were entirely irrelevant to the participants' task which was colour discrimination. The initial colour discrimination task (phase 1) was followed by a surprise recognition memory test of items presented in phase 1. The main prediction in this experiment was that if gaze cueing is automatic in the sense that it occurs independently of ongoing task demands, then items that had been seen to have been gazed at in phase 1 of the experiment (colour discrimination task) would be associated with greater recall in phase 2 (surprise recognition memory task) compared with the other items. Thus, this work relied on recognition memory as an index of the allocation of attention to items in the initial phase of the experiment. This ensured that the gaze cues in phase 1 of the experiment were always entirely irrelevant to the participants' task. However, against predictions, results across five experiments did not reveal any differences in the proportion of items recalled in phase 2 as a function of whether or not they had been previously gazed at in phase 1.

Taken together, the results from Chapter 3 found no evidence that gaze cues shift attention when those cues are entirely irrelevant to the participants' task. This suggests that these cues do not shift attention in an entirely automatic fashion. These results are consistent with findings in the attention literature more generally which demonstrate that many effects which are related to the orienting of spatial attention are contingent, at least to some extent, on top-down factors such as task demands (Most et al, 2005; Yantis & Jonides, 1990).

Chapters 4 and 5 addressed the second goal of this thesis, which was to investigate the interaction between eye gaze, emotional expression, and attention. Specifically, the experiments reported in Chapter 4 examined whether gaze direction modulates the way attention is allocated to emotional facial expressions. The experiments in this chapter made use of the dot-probe paradigm in order to assess the allocation of attention to task-irrelevant faces as a function of gaze and emotional expression. There was clear evidence that attention is biased towards the location of threat but no evidence that this effect is modulated by gaze direction and no evidence that attention is allocated to the face on the basis of gaze alone (contrary to studies by von Grünau and Anston (1995) and Senju et al, (2005)). The only occasion that gaze did influence the allocation of attention was when both of the stimulus faces in the dot-probe task had angry expressions. In this condition, attention was biased towards the location of direct gaze. This is consistent with data suggesting that angry faces are processed more efficiently when they have direct gaze compared to averted gaze (Macrae, Hood, Milne, Rowe, & Mason, 2002; Adams & Kleck, 2003).

Together, the data from this chapter support the notion that the allocation of attention is modulated by emotional facial expressions and tends to be biased towards the location of threat. Furthermore, the data suggest that gaze direction only influences the allocation of attention in limited circumstances; in this case if competition for attention arises between two angry faces. Also, in agreement with the findings from Chapter 2, there was no evidence to suggest that direct gaze draws attention to its location.

Chapter 5 extended the work from Chapter 4 by examining how individual differences in anxiety influence the allocation of attention to facial signals. Such individual differences are known to influence the allocation of attention to threat-related information more generally (e.g. Mogg & Bradley, 1998). The one experiment in Chapter 5 largely replicated the procedure used in Experiment 10 except participants were allocated into low and high anxiety groups. Results for the high-anxious participants supported the predictions; attention was allocated to the location of the angry facial expressions regardless of gaze direction. However, results for the low-anxious participants did not support the predictions; no bias was shown towards the location of the angry facial expression at all. This study confirmed the results from Chapter 4 in the sense that when emotion and gaze cues co-vary, attention is allocated on the basis of the emotion cue and not the gaze cue. This study also supported the notion that high-anxious individuals tend to show an attentional bias towards threat-related stimuli.

In summary, while it is clear from the experiments in this thesis that the allocation of attention to a face is influenced by the emotional facial expression it adopts, there is no compelling evidence that the allocation of attention to a face (either with or without a specific emotional expression) is similarly influenced by its gaze direction. This is despite assertions from previous research using the visual search task that direct gaze draws visual attention to its location (von Grünau & Anston, 1995; Senju et al, 2005). However, as discussed in Chapter 2, these previous experiments contain a critical confound that make the interpretation of the data difficult. A recent attempt to investigate this issue suggests that once the confound is removed, the apparent search advantage for direct gaze also disappears (Cooper, Law, & Langton, in preparation). If the conclusion that direct gaze draws attention in the visual search task is rejected, this is consistent with the repeated inability to find any similar effects in this thesis. This suggests that while direct gaze is a very important socially meaningful stimulus that can <u>hold</u> attention at its location (i.e. it is difficult to disengage attention from direct gaze), it does not <u>draw</u> attention to its location.

This finding has important implications for understanding the type of facial information that is processed preattentively. As discussed previously, past studies suggest that attention may be drawn to the location of a face if it is surrounded by other non-face stimuli (Hershler & Hochstein, 2005), and drawn to an angry face more readily than to a happy face (Öhman et al, 2001; Chapters 4 and 5 this thesis). This implies that facial information is prioritised over the processing of non-facial information, and, furthermore, particular types of facial signal (i.e. threat) are prioritised over others. It is assumed that preattentive mechanisms are responsible for such effects (Johnston & Dark, 1986). However, given the evidence from this thesis that gaze direction does not influence the allocation of attention to faces, this suggests gaze direction is not analysed preattentively. This, in turn, suggests that the direction in which the eyes are looking, and by implication, the direction in which they are sending a meaningful signal, make no difference at the preattentive stage in processing. This is consistent with the conclusion that attention is biased to allocate resources to faces in general, and angry faces in particular, but the personal relevance of those stimuli is not analysed until a later stage in processing.

While it seems that gaze direction is not processed preattentively, the current experiments do not provide any information about whether other cues to the direction of another's attention might be processed preattentively. For example, head direction gives a good indication of where another person is attending. The difference between direct and averted <u>head</u> direction is perceptually much larger compared with the difference between direct and averted <u>gaze</u> direction. Thus the former might be more likely to be discriminated preattentively and could modulate the allocation of attention to both faces and emotional expression. Further research is needed to clarify this issue.

Overall, the studies in this thesis highlight the important role that meaningful facial signals play in the allocation of visual attention. They suggest that attention can be automatically allocated to complex visual stimuli, such as faces, on the basis of the specific signal that is being communicated. This is in common with a number of recent studies that have investigated the relationship between facial signals and attention (Friesen & Kingstone, 1998; Langton & Bruce, 1999; Öhman et al, 2001; Eastwood et al, 2001; Fox et al, 2001; Vuilleumier & Schwartz, 2001; Koster et al, 2004; Senju & Hasegawa, 2005; Hunt et al, in press). Despite this work, there currently exists no theory of visual attention that explicitly incorporates this evidence.

To highlight the significance of this omission it is possible to consider the case of the amygdala. The amygdala has been identified as playing a leading role in the processing of stimuli with social meaning (Adolphs, Tranel, & Damasio, 1998) and especially those stimuli related to fear and aggression (Adams et al, 2003; Liu, Ioannides, & Streit, 1999). Indeed, the amygdala's response to fearful faces and highly arousing emotional scenes appears to be unaffected by whether or not spatial attention is specifically directed at them (Vuilleumier, Armony, Driver, & Dolan, 2001; Lane, Chua, & Dolan, 1999; although see Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). Furthermore, re-entrant projections from the amygdala (and other limbic regions) back to occipital (visual) cortex have been implicated in enhancing visual processing of emotionally salient stimuli (Armony & Dolan, 2002; Lang, Bradley, Fitzsimmons, Cuthbert, Scott, Moulder, & Nangia, 1998). These projections, and the enhanced processing of the stimuli with which they are associated, are likely to be at least partly responsible for the attentional biases that are often observed towards negative facial expressions (Pourtois, Grandjean, Sander, & Vuillleumier, 2004).

Given that the amygdala seems to play a specific role in the allocation of attention to socially meaningful stimuli, and given that our lives are dominated by the processing of these stimuli, it is somewhat surprising that its role is not recognised in contemporary theories of attention that propose a neural architecture (e.g. Bundeson, Habeskost, & Kyllingsbaek, 2005; Deco & Rolls. 2005; Hamker, 2005; Serences & Yantis, 2006; Shipp, 2004). Where the amygdala's role *is* recognised is in theories of emotion and attention (e.g. Armony & Le Doux, 2000; Le Doux, 1996). However, by their very nature, these theories do not attempt to incorporate data from more 'traditional' studies of attention that are concerned with the processing of 'simple' stimulus features such as colour and orientation (e.g. Treisman, 1988).

The observation that the amygdala influences the processing of emotionally salient stimuli through reciprocal connections to primary visual areas (V1; e.g. Armony & Dolan, 2002) is entirely consistent with other evidence showing that connections from higher cortical areas such as the intraparietal sulcus modulate the processing of other, less socially meaningful stimuli (e.g. lines) in area V1 (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000). The role of such re-entrant pathways in the allocation of attention more generally (excluding those associated with the amygdala) is already recognised in some contemporary accounts of attention (e.g. Di Lollo, Kawahara, Zuvic & Visser, 2001; Spratling & Johnson, 2004; Shipp, 2004). This being the case, the data from experiments showing, for example, an attentional bias towards the location of potential threat (e.g. Chapter 4, this thesis), could be accommodated by recognising the amygdala as an important structure in the allocation of attention to emotional stimuli in general, and threat-related stimuli in particular (see Vuilleumier, 2005). This inclusion would help promote a more comprehensive understanding of attention.

However, this is not the only omission from recent theories of attention. Data from this thesis (Experiment 13) highlight the influence that individual differences in mood-state can have on the allocation of attention. Again, this is in common with a number of studies investigating how individual differences in mood-related variables such as anxiety can affect the way attention is allocated (Mogg & Bradley, 1998; Bradley et al, 1997; Macleod et al, 1986; Fox, 2002; Koster et al, 2005).

However, the impact that such individual differences can have on the way attention is allocated is also not specifically acknowledged in theories of visual attention (e.g. Wolfe 1998; Desimone & Duncan, 1995; Yantis, 1996; Bundeson, Habeskost, & Kyllingsbaek, 2005; Deco & Rolls. 2005; Hamker, 2005; Serences & Yantis, 2006; Shipp, 2004) while all would recognise the importance of other top-down factors such as beliefs, goals, and expectations.

Together, these two omissions reflect the fact that much work in the study of attention has traditionally focussed on how stimulus features such as colour and orientation are processed rather than examining the processing of more socially meaningful stimulus properties (Fox, 2005). Unfortunately, this has led to a situation where much of the data collected in the pursuit of an understanding of the mechanisms driving attention may not generalise beyond the limited confines of the paradigms within which they are obtained (Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003). This suggests future theoretical treatments of attention need to take into account both the nature of the stimulus and the mood-state of the observer if they are to describe adequately the processes of attention as they occur outside of the laboratory.

Although the experiments in this thesis, as well as related experiments (e.g. Mogg & Bradley, 1998; Bradley et al, 1997; Macleod et al, 1986; Koster et al, 2005; Friesen & Kingstone, 1998; Langton & Bruce, 1999; Ohman et al, 2001; Eastwood et al, 2001; Fox et al, 2001; Fox, 2002; Vuilleumier & Schwartz, 2001; Koster et al, 2004; Senju & Hasegawa, 2005; Hunt et al, In press) are moving the field towards an understanding of the relationship between meaningful social signals and attention, they are still open to at least two major criticisms relating to the ecological validity of the stimuli. Firstly, the dynamic nature of faces encountered out-with the laboratory is not represented in the static images that are routinely used in these experiments. This is despite the fact that it has already been established that dynamic facial stimuli are processed in a manner that is different to their static equivalents, and this is true for various aspects of the face such as emotion (Sato & Yoshikawa, 2004) and attractiveness (Chang, 2005), as well as recognition (Lander & Bruce, 2003).

Secondly, and even more fundamentally, studying the effects of meaningful social signals through the use of photographic images may be a useful first step, but is an ultimately redundant method if the goal is to establish what attentional mechanisms operate in the 'real world'. It is easy to see why the study of attention to socially meaningful signals such as emotional facial expressions has largely relied on paradigms adapted from the mainstream attention literature. These paradigms allow a great deal of control over variables and have well-established mechanisms for interpreting the data. Furthermore, this approach has already garnered some important advances. For example, the finding that centrally presented gaze cues can shift attention (e.g. Friesen & Kingstone, 1998) went against the notion that such attentional shifts could only be produced by sudden onset stimuli presented in the periphery (Kingstone et al, 2003). This has served to highlight the important role that such stimuli can play in a broader understanding of the way attention is allocated.

However, there is reason to suspect that the way attention is allocated in response to pictures of faces may be quite different from the way attention is allocated in response to actual faces. As already discussed, the way attention is allocated to any given scene is heavily influenced by top-down factors such as beliefs and expectations (e.g. Most et al, 2005). Apart from the perceptual differences that separate facial images from live faces (e.g. static vs. dynamic, 2-D vs. 3-D), a picture of another face is merely a representation of that face captured in time. In contrast, a live face belongs to another human being and has far more potential for interaction. This distinction is important because the viewer knows that while the photographic image may appear to be sharing mutual gaze, it is in fact not real. In contrast, if the viewer and the live face share mutual gaze the viewer knows that the live face is looking back at them, that they too are an agent with their own thoughts and feelings (Baron-Cohen, 1995). With it, this difference brings social meaning. For example, depending on the context, a prolonged period of mutual eye contact between two individuals can be a sign of mutual attraction or mutual animosity (Emery, 2000). However, given that mutual eye contact with a photograph is, by its very nature, only an approximation of an actual event that only involves one participant, none of the richness of the live interaction can be replicated.

Thus, examining attentional effects that arise in response to photographic images of socially meaningful cues is a useful way to show how the processing of such cues can provide insights into how attention might operate in the 'real world'. However, the next step must be to go beyond studying representations of facial signals and study the actual signals themselves. Without such a step, data concerning attentional effects that arise in response to such meaningful facial signals may, at best, not tell the full story, and at worst, be fundamentally misleading.

A useful move forward in this regard would be to measure eye movements as people look at representations of faces (e.g. pictures and videos) compared with faces themselves. It would be predicted that the allocation of attention to a live face would be qualitatively different to the allocation of attention to faces in the picture and video conditions. This result would support the notion that research into the allocation of attention to socially meaningful stimuli needs to be conducted with consideration for the presentation of stimuli as they are ‘normally’ encountered.

This is not to say that research that has not been conducted in this way needs to be disregarded. On the contrary, it can guide the direction of future research in a meaningful way. However, given that the importance of studying the relationship between socially meaningful stimuli and attention has been widely acknowledged (e.g. Friesen & Kingstone, 1998; Driver et al, 1999; Langton & Bruce, 1999; Fox, 2005; Vuilleumier, 2000, Ohman et al, 2001), it necessarily follows that researchers should ensure that what they are studying are phenomena that exist out-with the laboratory (Kingstone et al, 2003).

In summary, this thesis has sought to investigate the relationship between meaningful facial signals and attention. The presented evidence suggests that gaze does not influence the allocation of attention to the extent that might have been expected from a number of avenues of previous research. Firstly, despite previous work, no evidence was found that direct gaze draws attention to its location. Secondly, averted gaze does not appear to shift attention in a way that is independent of task demands. Thirdly, despite other previous research suggesting that differences in gaze direction modulate the <u>perception</u> of emotional facial expressions, the data from this thesis suggest that differences in gaze direction do not modulate the allocation of <u>attention</u> to emotional facial expressions, except when those expressions are angry. Consistent with other work, data from this thesis did support the notion that emotional information from facial expressions can guide the allocation of attention in an automatic fashion and that this can be modulated by the individuals' level of anxiety.

Together, this research highlights the importance of studying the relationship between attention and meaningful facial signals. It is suggested that past theoretical treatments of visual attention have overlooked this social dimension, and, in doing so, have risked being relevant to phenomena that exist only within the confines of the laboratory. Future theories of attention need to incorporate findings from the literature on social aspects of attention. Furthermore, future attention research should be more mindful to addresses issues that are relevant out-with the laboratory setting.

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